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PHYSIOGRAPHIC SECTIONS OF THE GUIANA HIGHLANDS, VENEZUELA AND G--ETC(U)

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# PHYSIOGRAPHIC SECTIONS OF THE GUIANA HIGHLANDS

## VENEZUELA AND GUYANA

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FINAL REPORT

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COLORADO 80840

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This research report is presented as a competent treatment of the subject, worthy of publication. The United States Air Force Academy vouches for the quality of the research, without necessarily endorsing the opinions and conclusions of the author.

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| REPORT DOCUMENTATION PAGE | | READ INSTRUCTIONS BEFORE COMPLETING FORM |
|---|---|---|
| 1. REPORT NUMBER<br>USAFA-TR-76-19 | 2. GOVT ACCESSION NO. | 3. RECIPIENT'S CATALOG NUMBER |
| 4. TITLE *(and Subtitle)*<br>PHYSIOGRAPHIC SECTIONS OF THE GUIANA HIGHLANDS VENEZUELA AND GUYANA | | 5. TYPE OF REPORT & PERIOD COVERED<br>FINAL REPORT |
| | | 6. PERFORMING ORG. REPORT NUMBER |
| 7. AUTHOR(s)<br>Major Charles L. Smith | | 8. CONTRACT OR GRANT NUMBER(s) |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS<br>Department of Economics, Geography and Management<br>United States Air Force Academy, Colorado 80840 | | 10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS |
| 11. CONTROLLING OFFICE NAME AND ADDRESS<br>DFEGM<br>USAF Academy, Colorado 80840 | | 12. REPORT DATE<br>APRIL 1976 |
| | | 13. NUMBER OF PAGES<br>42 |
| 14. MONITORING AGENCY NAME & ADDRESS *(if different from Controlling Office)* | | 15. SECURITY CLASS. *(of this report)*<br>Unclassified |
| | | 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE |

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for Public Release; Distribution Unlimited

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17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This report discusses the nature of the Guiana Shield and delimits meaningful subdivisions. The Shield contains the Guiana Lowlands, Guiana Hills, and Guiana Highlands, all physiographic provinces. To subdivide the Guiana Highlands into smaller units the geology, geomorphic features, soils, and vegetation were analyzed. This is in contrast with earlier studies which used river basins as physiographic sections. The analysis resulted in the formulation of three physiographic sections, the Sierra de Imataca, the Tepui Section, and the Western Highlands Section.

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## PART I

## PURPOSE

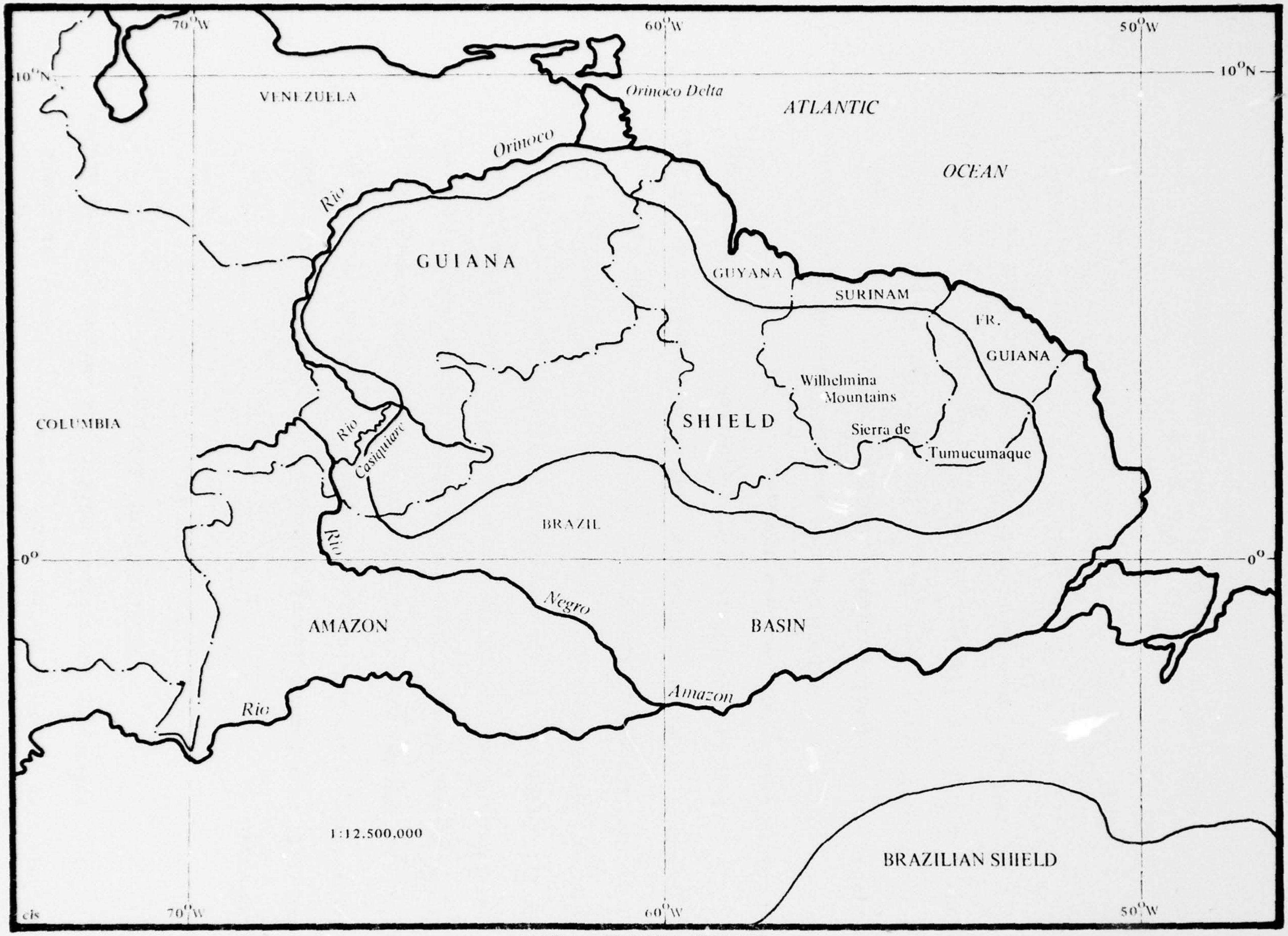
A relatively isolated and unknown region of South America, the Guiana Highlands lies primarily in Venezuela and Guyana and is part of the large Guiana Shield (see Map 1). The boundaries of the Guiana Highlands are extremely difficult to delimit, not only because data about the region is limited, but also because treatment of the region as a physiographic unit has been haphazard.

The purpose of this report is to define meaningful physiographic sections for the Guiana Highlands so that further analysis of the region will be easier and more systematic. First, Part II of the report discusses physiographic units and the criteria used to establish them. Part III, background to the problem of delimiting the Highlands, examines their relation to the Guiana Shield and roughly applies the concept of physiographic units to the Shield and the Highlands. Parts IV, V, VI, and VII examine in depth the geology, geomorphology and terrain, soils, and vegetation of the Highlands to lead finally, in Part VIII, to a formulation of physiographic sections of the Guiana Highlands.

## PART II

## PHYSIOGRAPHIC DIVISIONS

Many geographers and others interested in various forms of spacial analysis have discussed the concept of regions. Richard Hartshorne defines a region as "an area of specific location which is in some way




MAP 1 GUIANA SHIELD

distinctive from other areas and which extends as far as that distinction extends." Hartshorne also states that the individual studying a region should formulate the guidelines used to distinguish a region.[1]

Geologists and geographers use the term physiographic or natural region to refer to an area in which the topography, structure, landforms, soil, and vegetation are similar. The most widely employed guidelines for establishing such regions are based upon the works of N. Fenneman. In a 1914 article in the Annals of the Association of American Geographers, Fenneman expresses his belief that a system of physiographic regions should benefit both the geographer and the geologist. He states that soil and topography are the end products of the physiographic history of an area and therefore are among the most fundamental bases for defining different physiographical units. If the topography of an area is controlled by the geologic structure, then structure becomes extremely important in delimiting divisions.[2]

In late 1914, the Association of American Geographers established a committee to devise a systematic method for dividing the United States into distinct physiographical regions. The committee, with Fenneman as chairman, devised a system using four levels of classification. The largest units, called major divisions, are based primarily upon geological structure as exemplified by the Appalachian Highlands. Major divisions

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[1] Richard Hartshorne, Perspective on the Nature of Geography, (Chicago: Rand McNally and Co., 1959), p. 130.

[2] N. M. Fenneman, "Physiographic Boundaries Within the United States," Annals of the Association of American Geographers, IV (1914), p. 85.

are subdivided into physiographical provinces where a distinctive structural framework gives rise to unique or distinctive landforms. An example of a physiographical province is the Appalachian Piedmont. Units in the next smaller category, the physiographical sections, are considered to be homogeneous regions established on the basis of surface and sub-surface geology, geomorphology, soils, and vegetation. The Piedmont Lowlands of the United States is such a physiographical section. Districts, the smallest of the physiographical units created, are based upon variations in relief, altitude, etc. Within the Piedmont Lowlands section, the six Triassic Basins of Virginia are districts. In defining the four physiographic units, Fenneman says that each is "an area which is characterized throughout by similar or closely related surface features, and which is contrasted in these respects with neighboring areas."[3] This system of regionalization has been used extensively in the United States and has been applied to other areas of the world.

## PART III

## BACKGROUND

### Guiana Shield

The Guiana Highlands is a part of the Guiana Shield, which is one of the oldest regions on the earth. This shield lies in the northern portion of South America between the Amazon and Orinoco rivers (see Map 1). It is one of several geologic shields which occur in various

[3]Fenneman, "Physiographic Boundaries," p. 89.

parts of the world; others are the Scandian, Angara, African, Deccan, East China, Australian, Laurentian, and Brazilian. Shields are large areas of crystalline Precambrian rock.[1] Most shields have been intruded by younger rocks and have undergone mountain building as well as metamorphism. Erosion has subsequently leveled the landscape, and today shields form some of the more stable portions of the earth.

Geomorphologists and geologists disagree among themselves about the relationship between the Guiana Shield and the Brazilian Shield. Some feel that the Guiana Shield and Brazilian Shield are united in the area of the foothills of the Andes Mountains.[2] Others feel that the two units are distinctly separate geologic features. A third group believes that the Guiana Shield and Brazilian Shield are portions of the larger Brazilian Platform, which at some time in the past was separated by the formation of the Amazon Basin.[3]

Regardless of its relation to the Brazilian Shield, the Guiana Shield is an extremely difficult entity to delineate, except in general and often vague terms. Some previous descriptions include the following: "an oval boss of Precambrian rock...generally oriented east to west... having a length of approximately 120 miles and a width of 600 miles."[4]

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[1]Joseph Van Riper, Man's Physical World (New York: McGraw Hill, 1971), p. 420.

[2]W. Singh, "Cordierite in the Pre-Cambrian Rocks of the South Savannas, British Guiana," Geological Magazine, XLII (1938), p. 37.

[3]U. G. Cordani, G. C. Melchel, and F. F. M. de Almaida, "Outline of the Precambrian Geochronology of South America," Canadian Journal of Earth Sciences, V (1968), p. 37.

[4]R. B. McConnell, "Planation Surfaces in British Guiana," Geographical Journal, CXXXIV (December, 1968), p. 516.

The courses of the Rio Orinoco, Rio Negro, and Rio Amazon are considered to be controlled by the edges of the shield; however, the shield has been reported to extend northward under the Orinoco delta and the savannas of the llanos.[5] The most commonly accepted view is that the Guiana Shield forms the core of that portion of South America enclosed by the Orinoco-Casiquiare-Negro-Amazon waterways, with extensions of the shield lying under the Orinoco and Amazon Basins. The shield proper is considered to be fringed with recent coastal deposits along its seaward borders. The Precambrian mass has been relatively stable for at least the last 1700 to 1800 million years.[6] The Guiana Shield obviously forms a major physiographic unit of South America on a scale similar to those of the Brazilian Shield and the Andean Mountains.

The Guiana Shield is not a true highland, although the term Guiana Highlands is often used to describe the same region. The entire unit is primarily a lowland with elevations generally under 1,000 feet. Only in the southeastern portion of Venezuela and the adjacent parts of Guyana and Brazil do true highlands occur. Here plateaus and mesas rise to over 9,000 feet. Low mountains and hills occur in central Surinam and along the border of the three Guianan nations and Brazil. The maximum elevation in these hills and mountains--4,200 feet--is in the Wilhelmina Mountains of Surinam.

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[5] Victor Lopez, "Venezuelan Guiana," in Handbook of South American Geology, ed. by William F. Jenks (New York: Geological Society of America, 1956), p. 331.

[6] Cordani, "Outline of the Precambrian Geochronology of South America," p. 628.

The Guiana Shield, therefore, consists of extensive lowlands with scattered steep-sided hills and ridges, limited uplands of low mountains and hills, and much taller highlands. The outer edges of the shield form the subdued lowlands, adjacent to the Atlantic Ocean, Amazon Basin, and Orinoco Llanos. In these lowlands the scattered inselbergs or isolated uplands may rise 2,000 feet above the generally flat terrain. The lower mountains and hills of the Guiana Shield are primarily of granitic composition, are relatively low in elevation, and have rounded profiles. These include the Wilhelmina Mountains of Surinam and the Sierra de Tumucumaque of Guyana, Surinam, French Guiana, and Brazil. The true highlands, which are enclosed by the Orinoco, Negro, Amazon, and Branco Rivers, are much higher in elevation than are other parts of the Guiana Shield and consist of large mesas, buttes, and plateaus.

## Physiographic Provinces of the Guiana Shield

Previous studies of the physiographic nature of the Guiana Shield have focused on portions of the region rather than the entire shield. In an article describing the geology of the Venezuelan portion of the Guiana Shield, Victor Lopez describes eight physiographical provinces. He gives no details for the system used to create the units, although the provinces obviously were formed along drainage basins.[7] This technique, which is employed in other studies, has no value other than allowing data related to a region to be more

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[7] Lopez, "Venezuelan Guiana," p. 333.

easily discussed. Reports concerning the geology and geography of Guyana separate that nation into four physiographical provinces--the coastal plains, the interior plains, the southern mountains, and the Pakaraima Mountains.[8] Brazilian studies tend to place all of northern Brazil into a category of lowlands with higher elevations along the northern borders. Presentations of physiographical regions such as these do not agree in concept and are generally incompatible since some are formulated on drainage, while others tend to consider geologic structure or topography.

Analysis of the entire Guiana Shield by this author, using the broad guidelines devised by Fenneman, indicates that the shield falls into the category of physiographic division. Each of three natural sub-units of the shield, the Guiana Lowlands, the Guiana Hills, and the Guiana Highlands, is a physiographic province (see Map 2).

### Guiana Highlands Physiographic Province

The physiographic province called the Guiana Highlands is a semi-continuous series of sedimentary highlands which lie over the basement rocks of the Guiana Shield and extend from a 1,000 to 3,000 foot high escarpment on the east to a large block of sandstone rising to over 9,000 feet in the west. This lateral distance is almost 600 miles. The northern and southern borders of the province are marked by an abrupt rise in elevation from the Orinoco Basin and the Amazon Basin. In

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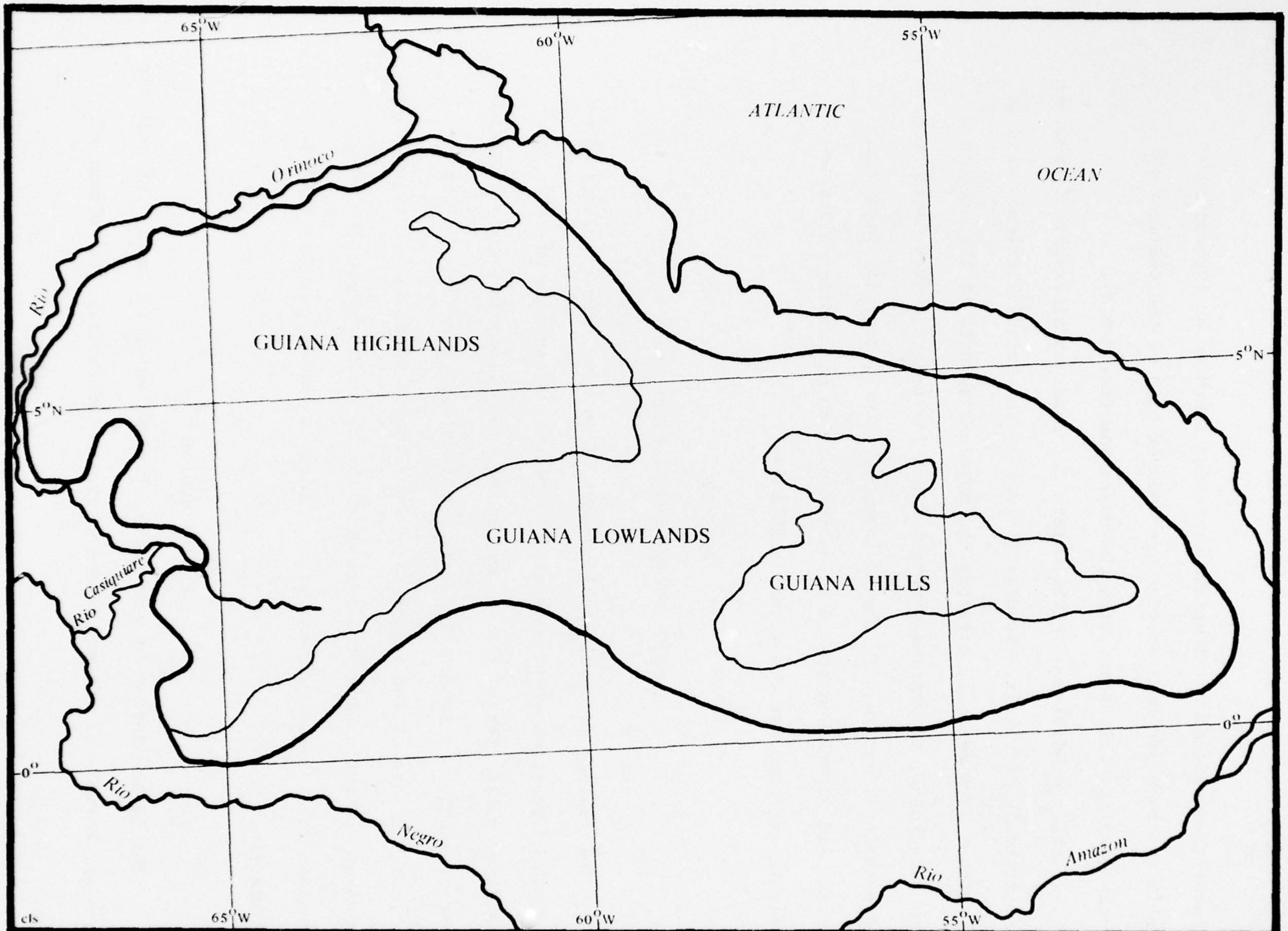
[8] Smith Bracewell, "British Guiana," in Handbook of South American Geology, ed. by William F. Jenks (New York: Geological Society of America, 1956), p. 91.




MAP 2 PHYSIOGRAPHIC PROVINCES OF THE GUIANA SHIELD

places the sedimentary materials have been intruded by igneous rocks, while in other portions erosion has removed much of the sedimentary rocks leaving hills mixed with the mountains (see Map 3).

Further subdivision of the Guiana Highlands physiographical province is extremely difficult. Studies discussing the Guiana Highlands tend to be either very general, covering the physical aspects of the area in a few paragraphs, or extremely detailed but limited to a very small area. Nevertheless, analysis of the geology, structure, terrain, landforms, soils, and vegetation should allow formulation of meaningful physiographic sections for the Guiana Highlands.

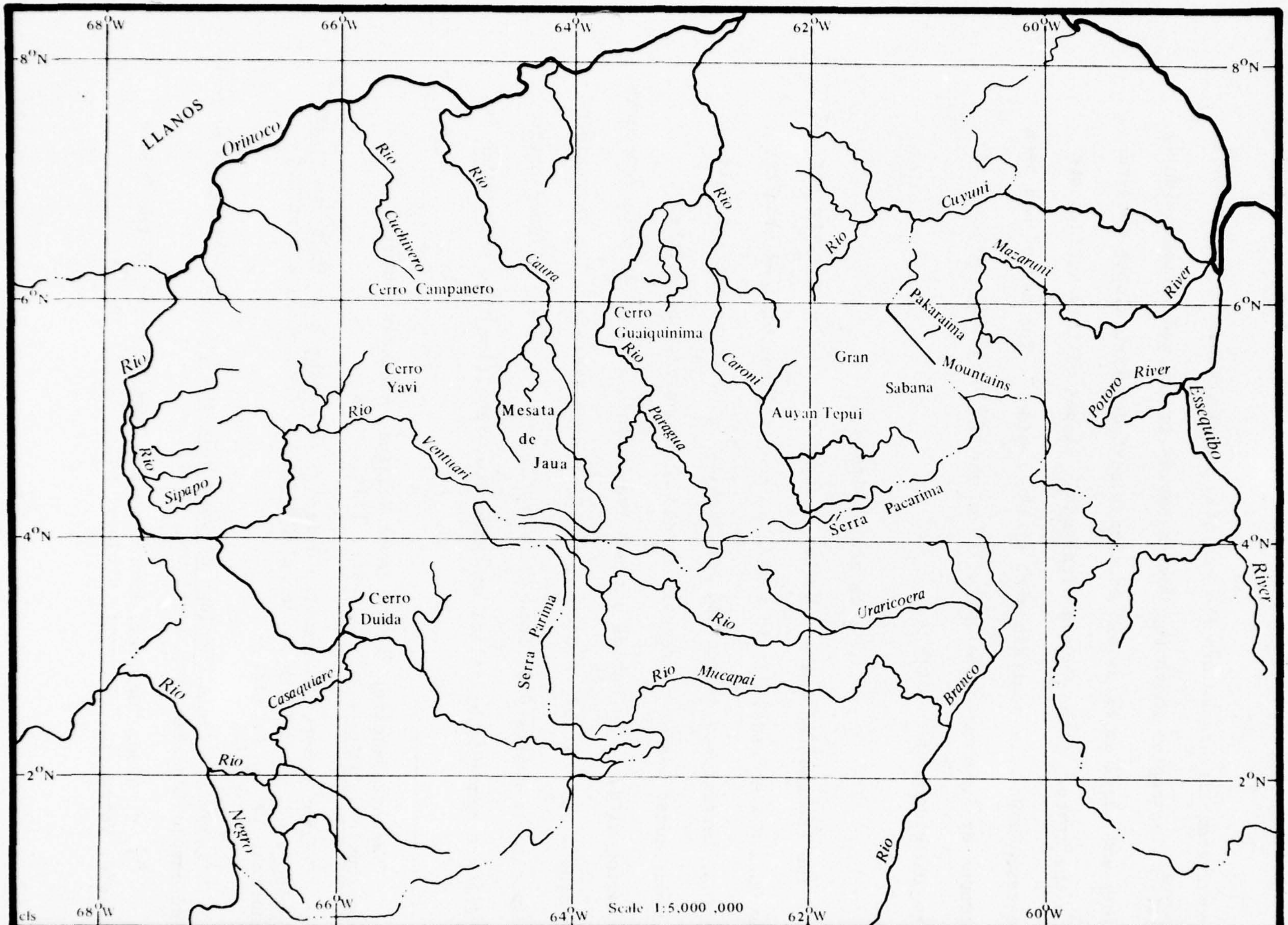
## PART IV

## GEOLOGY OF THE GUIANA HIGHLANDS

The geology and geological history of an area form the foundation for any discussion of physiographic regions. A sequence of early Precambrian rocks, termed the Guyana Series, underlies the Guiana Highlands physiographic province. The ancient crystalline rocks are covered throughout most of the region by younger rock formations. Three of these younger sequences have an effect upon the physiographic nature of the region: the Imataca Formation, the Volcanic Series, and the Roraima Formation.

### Guyana Series

The Guyana Series is a sequence of rocks which includes pink granitic gneiss, hornblende gneiss, mica schist, and quartzite. The oldest of



MAP 3 FEATURES OF THE GUIANA HIGHLANDS

these Precambrian rocks are the schists, which weather to form rounded hills.[1] The region where the Guyana Series is exposed is tectonically stable and consists of an old erosional surface which slopes outward from the center of the Guiana Highlands. Slopes of this surface are greatest toward the southern part of the region.[2] The series has been intruded by numerous dikes and sills of younger age which weather to form low ridges and outcrops.

## Imataca Series

The Precambrian Imataca Series occurs only in the northern part of the Guiana Highlands. It is a wide bank of feldspathic and granitic gneiss, ferruginous quartzite, and basalt.[3] The rocks are strongly metamorphosed and are intensely folded along an east or northeast trending axis.[4] The series extends from within Guyana far into Venezuela, forming a bank of low mountains, the Sierra de Imataca. The ferruginous quartzite is composed of iron oxide particles and recrystallized chert which are cemented by silica and siderite, resulting in a rock which is

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[1]Bassett Maguire, "Cerro de la Neblina, Amazonas Venezuela," Geographical Review, XLV (January, 1955), p. 49.

[2]Victor Lopez, "Venezuelan Guiana," in Handbook of South American Geology, ed. by William F. Jenks (New York: Geological Society of America, 1956), p. 332.

[3]Ralph A. Liddle, Geology of Venezuela and Trinidad (Ithaca, New York: Paleontological Research Institute, 1946), p. 5.

[4]J. C. Stam, "Geology, Petrology and Iron Deposits of the Guiana Shield, Venezuela," Economic Geology, LVIII (1963), p. 71.

tough and very resistant to erosion.[5] Water passing through the rocks leached some of the siderite and silica from the rock. These processes concentrated the iron oxide so that the present rocks have an iron content of 50 to 55 percent. In Guyana, the iron oxides have been removed by leaching and other processes, leaving some flat-topped, lateritic capped mountains.[6] In places these mountains contain low grade bauxite deposits.

## Volcanic Series

Also occurring in portions of the Guiana Highlands is a sequence of Precambrian basaltic tuffs and andesites which, in Venezuela, are referred to as the Pastora Series.[7] In Guyana a similar assemblage has several names, and in Brazil it is called simply the Volcanic Series. Much of this series appears to have been lava which filled depressions between monadnocks on an erosional surface at the top of the Guyana Series.[8] The entire sequence may be 3,000 feet thick with the greater thicknesses occurring in Guyana. These rocks are folded and in parts of Venezuela have a dip angle of 35 degrees. In the northeastern part

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[5] M. C. Lake, "Cerro Bolivar: US Steel's New Iron Ore Bonanza," Engineering and Mining Journal, CLI (August, 1950), p. 95.

[6] R. B. McConnell, "Planation Surfaces in British Guiana," Geographical Journal, CXXXIV (December, 1968), p. 510.

[7] Lopez, "Venezuelan Guiana," p. 331.

[8] O. Barbosa and A. de Romos, "Principle Aspects of the Geomorphology and Geology in the Territory of Rio Branco, Brazil," in Proceedings of the 5th Inter-Guiana Geological Conference (Georgetown, British Guiana: Geological Survey of British Guiana, 1962), p. 33.

of the region they form a chain of elongated ridges.[9] Some gold and diamond deposits are located in zones of contact between the Guyana Series and the Volcanic Series.[10]

Roraima Series

One of the major sedimentary units of the Guiana Highlands is the Roraima Series of sedimentary rocks. This consists of yellow, white, red, green, and black sandstone; conglomerate; quartzite; jasper; and shale. The yellow and reddish color of the prevailing sandstones is the result of iron oxide which cements the sandstone. The entire formation reaches a maximum thickness of 7,600 feet in the eastern portion of the area[11] (see Map 4).

Many intrusions by igneous materials into this formation have created some locally metamorphosed rocks. The major result of the intrusions has been the formation of numerous dikes and sills of dolerite and diabase, especially in Guyana.[12] In places such sills may be hundreds of feet thick.[13] Three of the larger intrusions have

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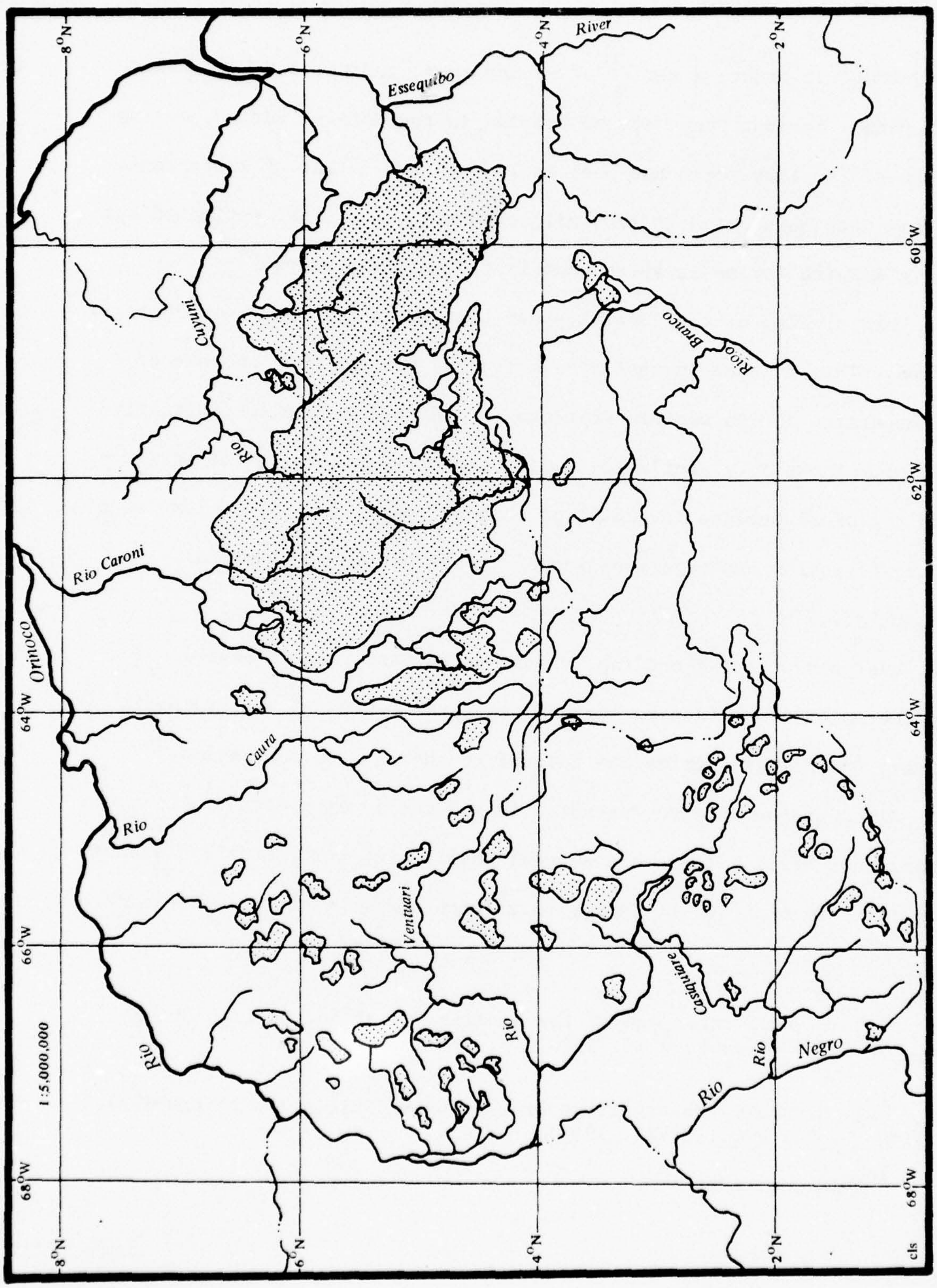
[9] Smith Bracewell, "British Guiana," in Handbook of South American Geology, ed. by William F. Jenks (New York: Geological Society of America, 1956), p. 93.

[10] G. M. Stockley, Geology of British Guiana and the Development of Its Mineral Resources (Georgetown, British Guiana: Geological Survey of British Guiana, 1955), p. 16.

[11] Lopez, "Venezuelan Guiana," p. 332.

[12] D. D. Hawkes, "Petrology of Guiana Dolerites," Geology Magazine, CIII (1966), p. 320.

[13] C. G. Dixon, "Notes on Basin Igneous Rocks in British Guiana," in Proceedings of the 5th Inter-Guiana Geological Conference (Georgetown, British Guiana: Geological Survey of British Guiana, 1962), p. 90.




MAP 4 OCCURRENCES OF THE RORAIMA SERIES

been eroded to create a series of escarpments, rapids, and waterfalls in Guyana. Because there are no fossils in the Roraima Series, dating of the sedimentary rocks has been based upon the dating of intrusions. One sill has been dated at 1700 million years. Thus, the estimated age of the Roraima Series is approximately 2000 million years.[14]

Most studies of the Roraima state that it is generally horizontally bedded. This is true in most of the region, but the beds in some of the mountains in the western portions of the region display distinctive folding. There is a gentle fold with an east-west axis in the series with a gradual decline in elevation towards the west. The eastern edge of the formation exposure consists of a long series of erosional escarpments.[15]

Analysis of cross-bedding, ripple marks, and local slumping together with other factors suggests that the source of the sediments forming the Roraima Series was located to the east of the region.[16]

Although the Roraima Formation is generally restricted to Venezuela, Guyana, and Brazil, there are several outliers at considerable distance from this region. In the Central Highlands and east of the Wilhelmina

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[14] N. J. Snelling, "Age of the Roraima Formation, British Guiana," Nature, LXLVIII (January 15, 1960), p. 1080.

[15] A. Gansser, "Observations on the Guiana Shield (South America)," Ecolog. Geol. Helv., XLVII (1954), p. 105.

[16] Ibid., p. 106.

Mountains lies Tafelberg. This isolated mountain is a triangular mesa of white, pink, and red sandstones.[17] Covering approximately 97 square miles, the mesa rises to 3,600 feet with the uppermost 2,600 feet composed of the Roraima Formation.[18] In the opposite direction from the Guiana Highlands, along the western edge of the Colombian Llanos, only 17 miles from the Andes, lies the Sierra de Macarena. This structure rises to 5,000 feet and is characterized by steep cliffs and flat-topped mesas. The mass is "believed to be a remnant of a tableland that extended through Venezuela to the Guianas."[19] Outliers of the Roraima Series in Brazil include Mesa Tepequem, which is composed of white sandstones, and the Serra Tucano, in a bend of the Rio Tucano, which is another area of the Roraima Formation[20] (see Map 5).

## PART V

## LANDFORMS OF THE GUIANA HIGHLANDS

Due to the large size of the region and the lack of comprehensive information, it is necessary to divide the Guiana Highlands physiographic province into smaller units to describe its terrain and landforms.

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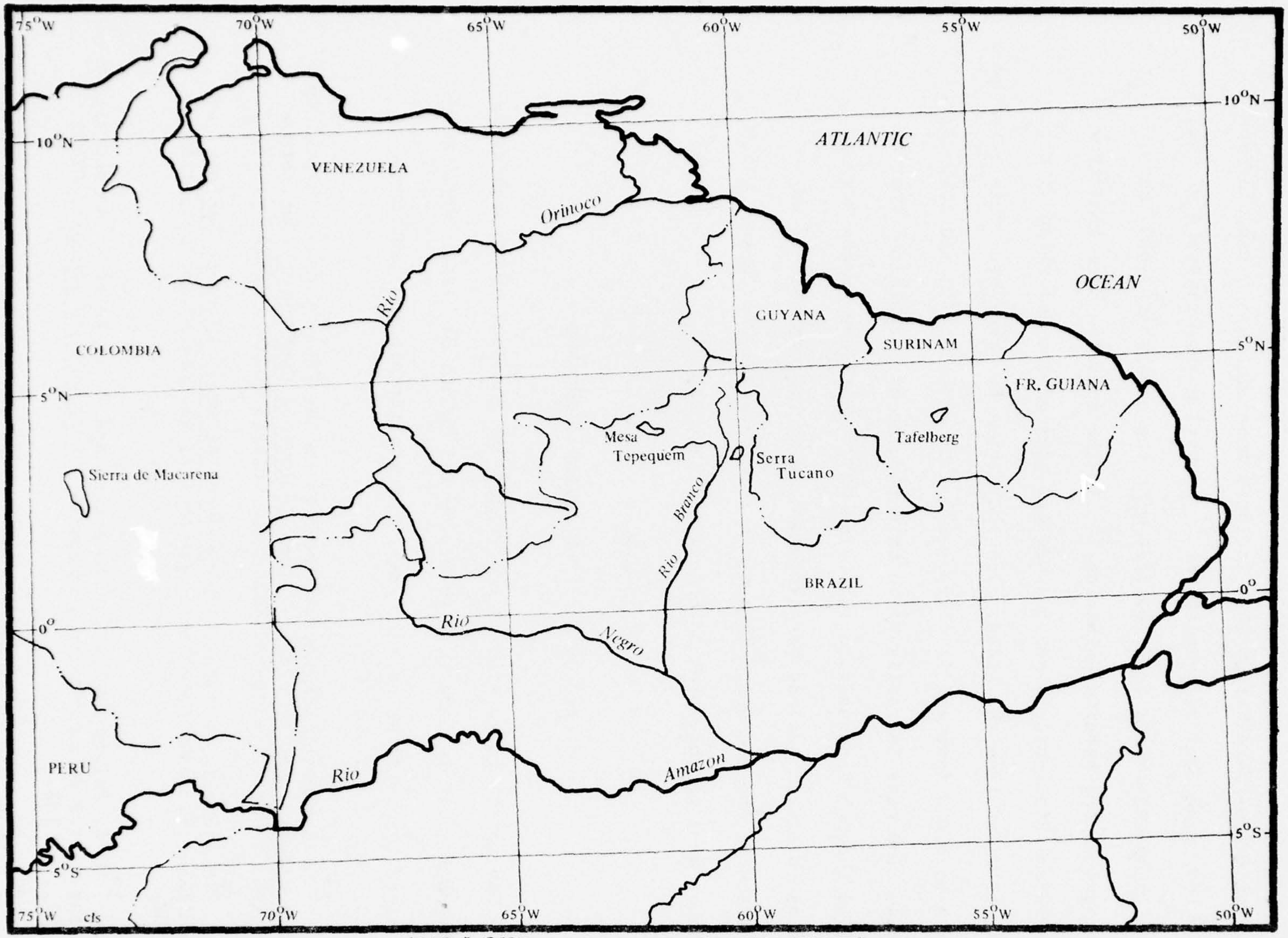
[17] H. Beckering Vinckers, "New Data on the Table Mountain Area," in Proceedings of the 5th Inter-Guiana Geological Conference (Georgetown, British Guiana: Geological Survey of British Guiana, 1962), p. 77.

[18] H. Schols, "Surinam," in Handbook of South American Geology, ed. by William F. Jenks (New York: Geological Society of America, 1956), p. 82.

[19] W. R. Philipson, C. C. Doncaster, and J. M. Idrobo, "An Expedition to the Sierra de la Macarana, Columbia," Geographical Journal, CXVII (1951), p. 188.

[20] Barbosa and de Romos, "Geomorphology and Geology of Rio Branco, Brazil," p. 33.




MAP 5 OUTLIERS OF THE RORAIMA SERIES

Because much of the existing data has been organized in terms of the various river systems, this type of organization will be most practical for this purpose. It must be remembered that these are not physiographic units; they are instead a tool for describing and analyzing the terrain and landforms of the physiographic province. The subregions are the Gran Sabana-Pakaraima Mountains, Upper Caroni-Paragua Basin, Upper Caura Basin, Upper Cuchivero Basin, Upper Orinoco-Ventuari-Negro Basin, and the Sierra de Imataca (see Map 6).

## Gran Sabana and Pakaraima Mountains

The Pakaraima Mountains of Guyana, the Gran Sabana of Venezuela, and the adjacent portions of Brazil form one large section, approximately 29,000 square miles, of the Guiana Highlands. The eastern border of this section also serves as the eastern border of the Guiana Highlands. The border is formed by a series of irregular escarpments from 1,000 to 3,000 feet high. These escarpments are the site of large and numerous waterfalls of the Pakaraima Mountains. Kaieteur Falls on the Potono River is the most famous of these falls with a single drop of 741 feet, or 5 times Niagara Falls. The falls are 300 feet wide during the rainy season and drop into a large amphitheater with cliffs that are about as high as the falls.[1] Other large waterfalls include

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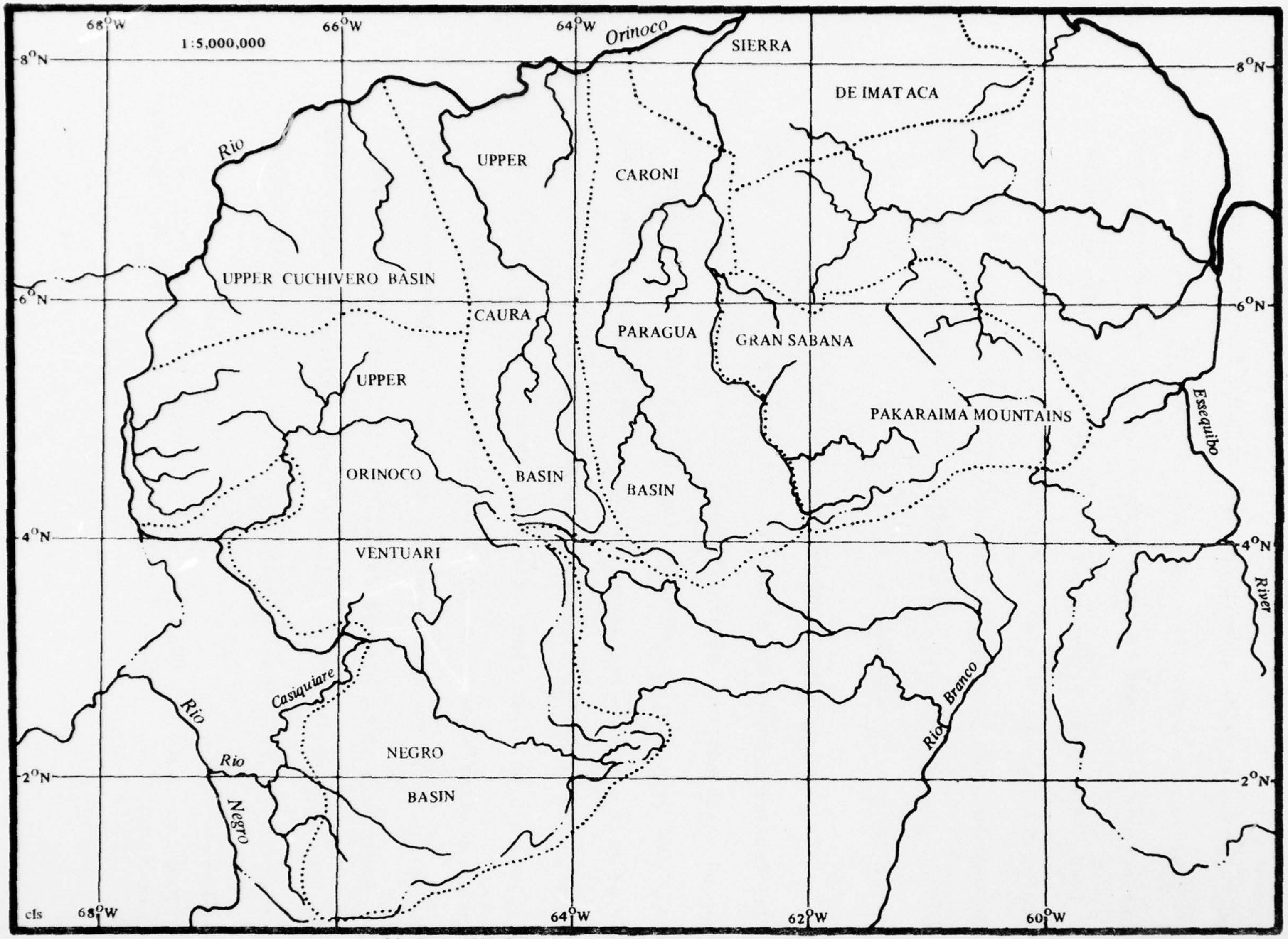
[1] Henry E. Crampton, "Kaieteur and Roraima: The Great Falls and Great Mountain of the Guianas," National Geographic, XXXVII (September, 1920), p. 231.



MAP 6 SUBREGIONS OF THE GUIANA HIGHLANDS

an unnamed falls which is 150 feet wide and drops 1,200 feet in a single fall.[2] Map 7 shows the location of these falls and other features of this region.

The Pakaraima Mountains are located to the west and above an escarpment which is believed to mark an ancient coastline.[3] The mountains consist of a rugged plateau from 2,000 to 3,000 feet high with a series of steep-sided mesas rising above the plateau. Rivers and streams of the region are deeply incised.[4] The general surface of the plateau rises in a series of terraces and escarpments to an average elevation of about 5,000 feet. The largest and tallest of the mesas of the Pakaraima Mountains are Ayanganna (6,700 feet), Wokomung (7,000 feet), and Kukenam (8,596 feet). The sides of Kukenam Mesa include 2,000 feet of the Roraima Series exposed in the steep escarpment.

The Pakaraima Mountains merge to the west into the Gran Sabana of Venezuela. The main feature of the border region between Guyana, Venezuela, and Brazil is a series of mesas which rise above the surrounding plateau. Rising to over 8,000 feet above sea level, these small mesas have tall sandstone cliffs. They extend northwestward

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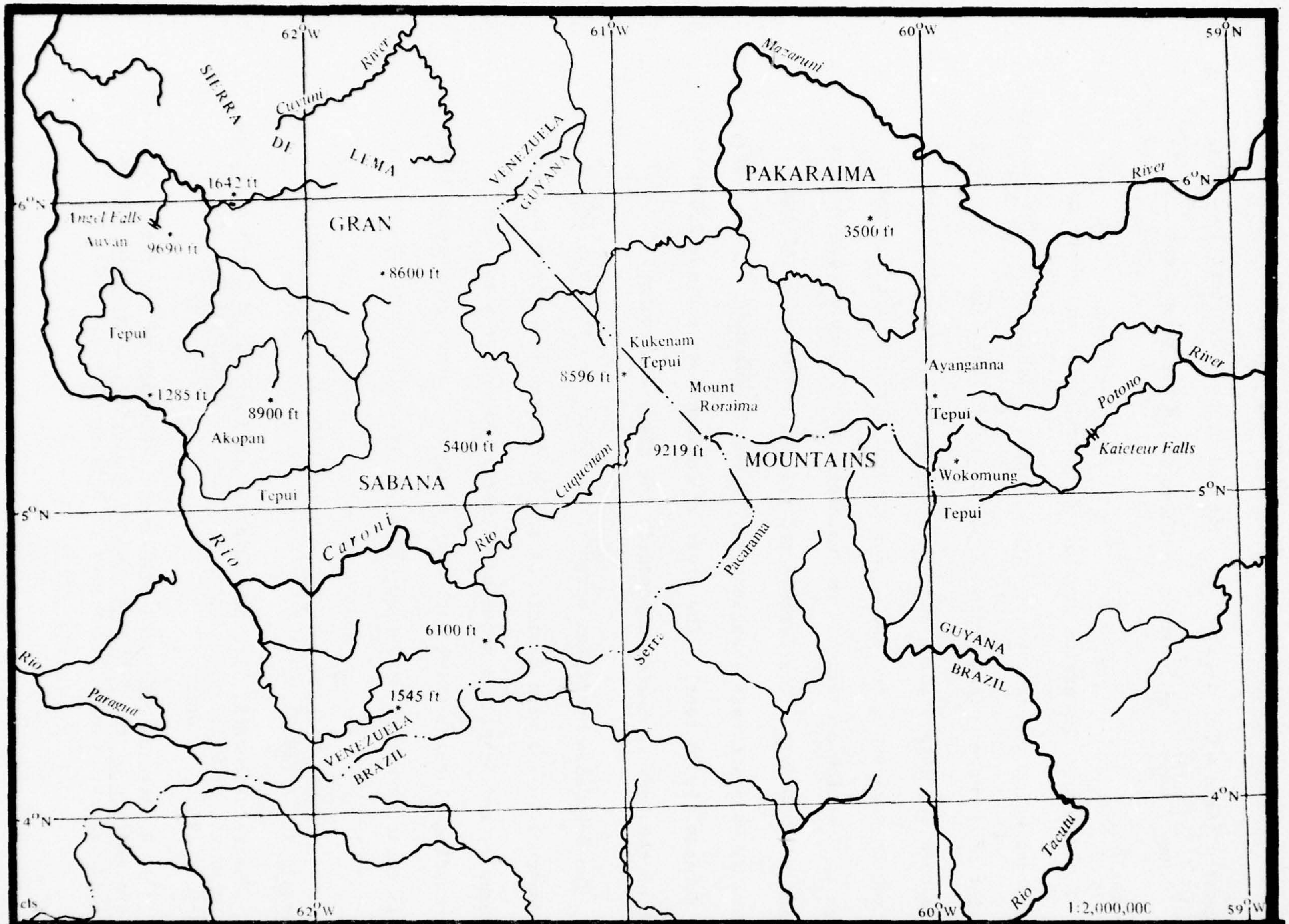
[2]Paul Zahl, "Two Waterfalls in British Guiana," Geographical Journal, XLIII (1930), p. 521.

[3]Smith Bracewell, "British Guiana," in Handbook of South American Geology, ed. by William F. Jenks (New York: Geological Society of America, 1956), p. 466.

[4]J. H. Bateson and M. G. Allderidge, "Geology of the Potaro Square," in Proceedings of the 5th Inter-Guiana Geological Conference (Georgetown, British Guiana: Geological Survey of British Guiana, 1962), p. 135.




MAP 7 GRAN SABANA AND PAKARAIMA MOUNTAINS

from the common Guyana-Brazil-Venezuelan border for approximately 20 miles. At the point where the three nations meet lies Mount Roraima. This is a 25 square mile, flat-topped mesa with 2,000 foot high cliffs. Reaching 9,219 feet, Mount Roraima forms the water divide between the Orinoco, Amazon, and Essequibo River systems. Water passing over the falls on the eastern escarpment of the mountain flows to the Atlantic Ocean via the Mazaruni and Essequibo Rivers, while water passing down the southern escarpment ends up in the Amazon River. All streams that issue from the western face of the mesa flow into the Caroni River and then into the Orinoco.

West of the Mount Roraima area the landscape becomes lower in elevation, and the Gran Sabana, or Great Savana, appears. This is a gently sloping plain from 3,000 to 4,500 feet above sea level with lower elevations near Brazil.[5] It is almost completely surrounded by taller mountains and plateaus. To the south the cuestas of the Serra Pacarama produce a long, irregular ridge, while to the north the Sierra de Lema rises to overlook the Cuyuni Basin in a series of mesas.

Across the valley of the Caroni at the western edge of the Gran Sabana is an area of broad, flat-topped mesas--the Western Mesas. These mountains rise 6,500 feet above the surrounding plains and include two

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[5] Eugene Wilson, "Eastern Llanos and Guiana Highland Savannas," (paper presented at the Southeastern Regional Meeting of the Association of American Geographers, Boone, North Carolina, 1972), p. 7.

very large and impressive mountains--Auyan Tepui and Akopan Tepui.[6] Auyan Tepui is an irregular-shaped elliptical mass 22 miles long and 16 miles wide, covering over 250 square miles and rising to a height of 9,690 feet.[7] The southern escarpment consists of three benches, each 2,000 feet high.[8] Auyan Tepui is the site of Angel Falls, the highest known falls in the world. Here the falls issue through an opening approximately 100 feet below the surface of the mesa and drop almost 3,300 feet in a single fall.[9] Akopan Tepui, which is south of Auyan Tepui, is similar in structure, but is much larger, covering about 8,300 square miles and with a single 3,200 foot escarpment on all sides except the north, where there are two benches. Rising above the surface of Akopan Tepui are several smaller mesas. To the west of the Gran Sabana lies the Upper Caroni-Paragua Basin.

## Upper Caroni-Paragua Basin

The major river of the Gran Sabana and eastern Venezuela is the 398 mile long Rio Caroni. The river begins at Mount Roraima as the Rio Cuquenam, flows westward through the Gran Sabana, and then turns

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[6] Tepui is the Carib Indian term for mesa.

[7] G. H. H. Tate, "Auyantepui: Notes on the Phelps Venezuelan Expedition," Geographical Review, XXVIII (1938), p. 459.

[8] Victor Lopez, E. Mencher, and J. H. Brineman, "Geology of Southeastern Venezuela," Bulletin of the Geological Society of America, LIII (1942), p. 853.

[9] H. F. Garner, "Derangement of the Rio Caroni, Venezuela," Revue de Geomorphologie Dynamique, XVI (1966), p. 61.

northward to form the western border of that region. North of the Gran Sabana, the land along the eastern bank of the Rio Caroni descends in a series of escarpments to an area of rolling plains. A series of low cuestas and mesas extending from the Sierra de Lema forms the water divide between this basin and the Guiana Lowlands. In the north the Sierra de Imataca replaces the mesas (see Map 8).

The remaining landscape within the Caroni-Paragua Basin has been described as "isolated mesas and ranges of hills." The numerous waterfalls on the Caroni indicate a surface which resembles a "gigantic low inclination staircase."[10] The occurrence of these waterfalls and rapids on the Caroni is an indication of the large hydroelectric potential of the rivers of the Guiana Highlands. A portion of this potential has been realized on the lower Caroni where there are two large dams and hydroelectric plants.

Exploration and geological studies within the drainage area of the Caroni River have been concentrated in either the Gran Sabana or the Sierra de Imataca; hence, there is little data available concerning the remainder of the region. The major tributary of the Caroni is the 360 mile Rio Paragua which parallels the Caroni for about 200 miles before joining it.[11] In the area between these two rivers are the largest and

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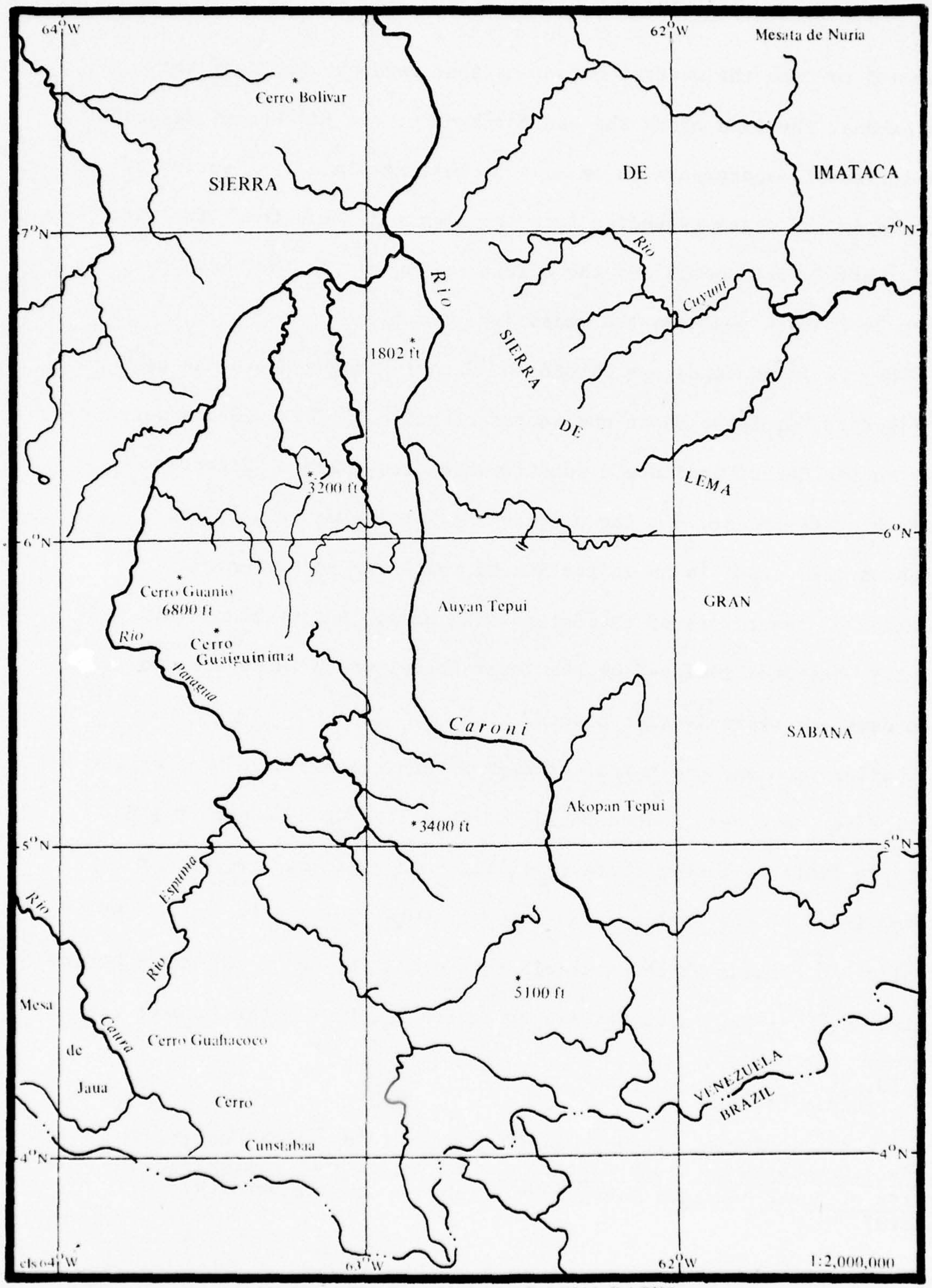
[10] Ibid., p. 63.

[11] U.S. Air Force, Arctic, Desert, Tropic Information Center, Survival Geography of South America: A Survey of the Jungles and Deserts of South America (Montgomery, Alabama: Air University, undated).




MAP 8 UPPER CARONI-PARAGUA BASIN

highest mesas of the Caroni-Paragua Basin. Composed of the sandstones and conglomerates of the Roraima Series, these mountains have many steep cliffs and reach a maximum elevation of about 6,900 feet at Cerro Guaiguinima. This mountain is actually a small mesa which rises from a large upland formed of the Roraima Series. The upland covers approximately 5,560 square miles and varies in elevation from 3,000 to 5,000 feet. Intrusions into this portion of the Guiana Highlands have resulted in many waterfalls. The Rio Paragua flows over several of these waterfalls, and one of its tributaries, the Espuma, passes over a 500 foot high falls.[12] To the west of the Caroni-Paragua Basin lies the Upper Caura Basin.

## Caura Basin

The Rio Caura, like the Rio Caroni, is a large tributary of the Rio Orinoco, and the majority of its 335 mile length lies in the Guiana Highlands. Approximately 50 miles south of the Rio Orinoco the landscape along the Rio Caura changes from a flat to rolling plain to an area of low rugged ranges and hills. Flat-topped mountains with perpendicular sides also are present. Granitic intrusions in the area form spectacular cliffs such as at Cerro la Prison[13] (see Map 9). The Para Falls on the Caura are an impressive crescent-shaped series of five

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[12] Marco-Auralio Villa, Geografia de Venezuela (Buenos Aires: Fundacion Eugenio Mendoza, 1961), p. 104.

[13] Llewelyn Williams, "The Caura Valley and Its Forests," Geographical Review, XXXI (1941), p. 410.

falls and rapids with a total drop of 220 feet. These falls are important because the rocks upstream are of the Roraima Formation while those downstream are of the Imataca and Volcanic Series. The Roraima Series is responsible for the numerous large mesas and tablelands in the upper reaches of the basin. Achava Mountain to the east of the Caura River has been described as a "solid square-shaped, fortress-like mass."[14] Achava is the first of a series of mesas lying east of the Caura River. Cerro Ameha has a fairly flat top and bare yellow to gray cliffs, while Cerros Arawa and Arichi have "awe-inspiring" cliffs with a narrow gorge cutting into Ameha.[15] Two large uplands, also of the Roraima Series, occur in the southern portion of the Upper Caura Basin. The Sierra Peyuami, which contains a higher mesa, Cerro Guahacoco, reaches 8,200 feet. Cerro Cunstabaa, the other upland, lies adjacent to the Venezuela-Brazil border.

The Rio Caura begins in the Mesata or Altiplano de Jaua as the Rio Merevani.[16] This upland, which covers 4,480 square miles, has an average elevation above 2,600 feet. Several smaller mesas rise above the Mesata to elevations over 5,200 feet. Mesata de Jaua is composed of Roraima sandstone and conglomerate. The Rio Erebario,

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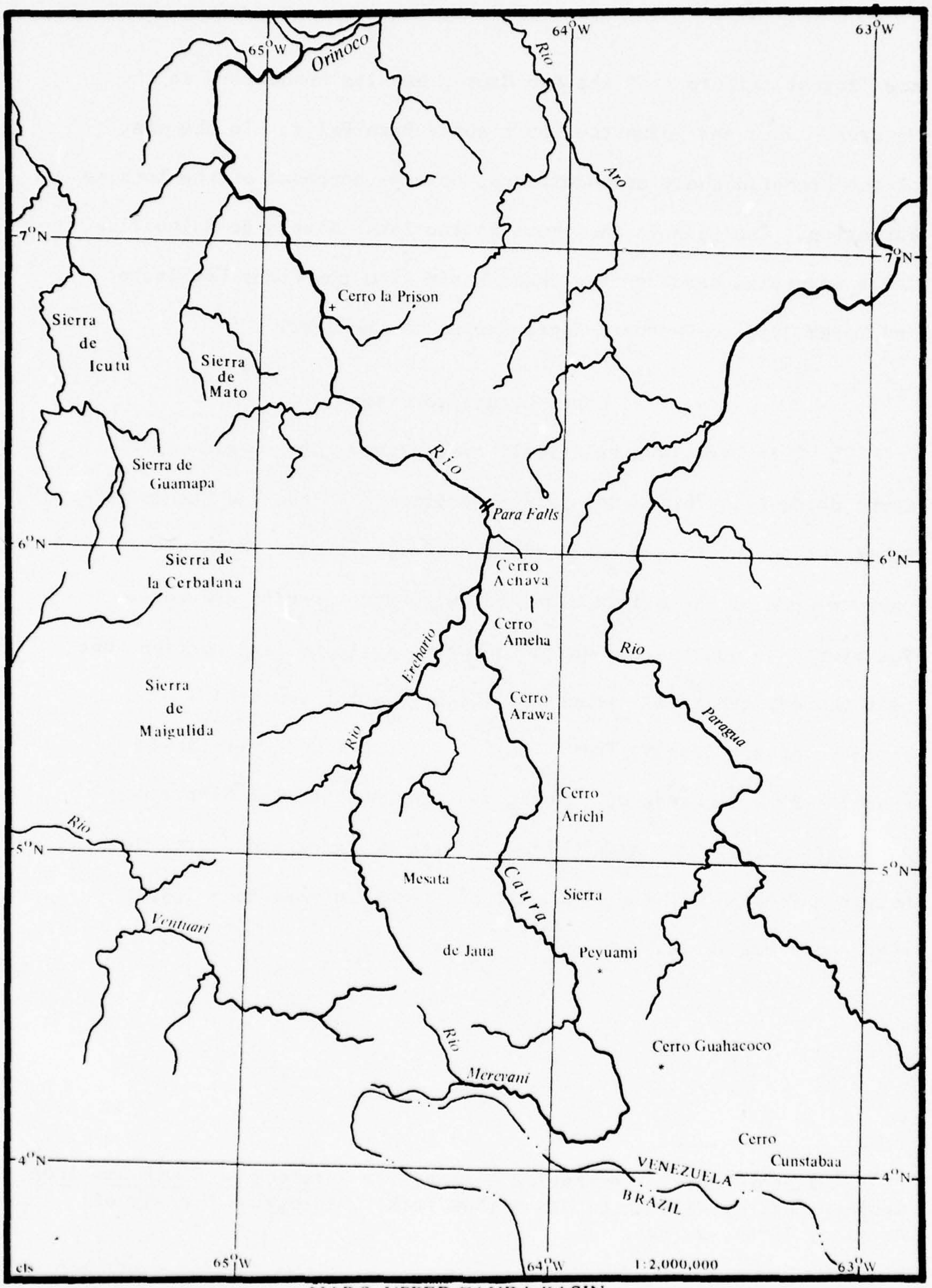
[14] Engene Andre, A Naturalist in the Guianas (London: Smith, Elder and Co., 1904), p. 210.

[15] Ibid., p. 237.

[16] Villa, Geografia de Venezuela, p. 103.




MAP 9 UPPER CAURA BASIN

the largest tributary of the Rio Caura, has its headwaters in the Mesata de Jaua and joins the Caura above Para Falls. To the west of the Erebario there are additional uplands composed of the Roraima Formation. Included in the group is the large Sierra de Maigualida. These mountains separate the Caura Basin from the Upper Cuchivero and Upper Orinoco-Ventuari-Negro Basins to the west.

## Upper Cuchivero Basin

The Cuchivero is a relatively small river which begins in Cerro de Icutu. The region is not restricted to the Rio Cuchivero Basin, but includes many small river basins. It is a relatively unknown area of the Guiana Highlands with much granite and gneiss. The Sierra de Guamapa, of which the Cerro de Icutu is a portion, has flat-topped, table-like mountains which give the impression of remnants of the Roraima Formation.[17] The Upper Cuchivero Basin contains several areas of tabular features such as the Sierra de Paraguara, Sierra de la Cerbalana, Sierra de Mato, and Sierra de Chivaple (see Maps 9 and 10). All of these are more than 2,500 feet above sea level.

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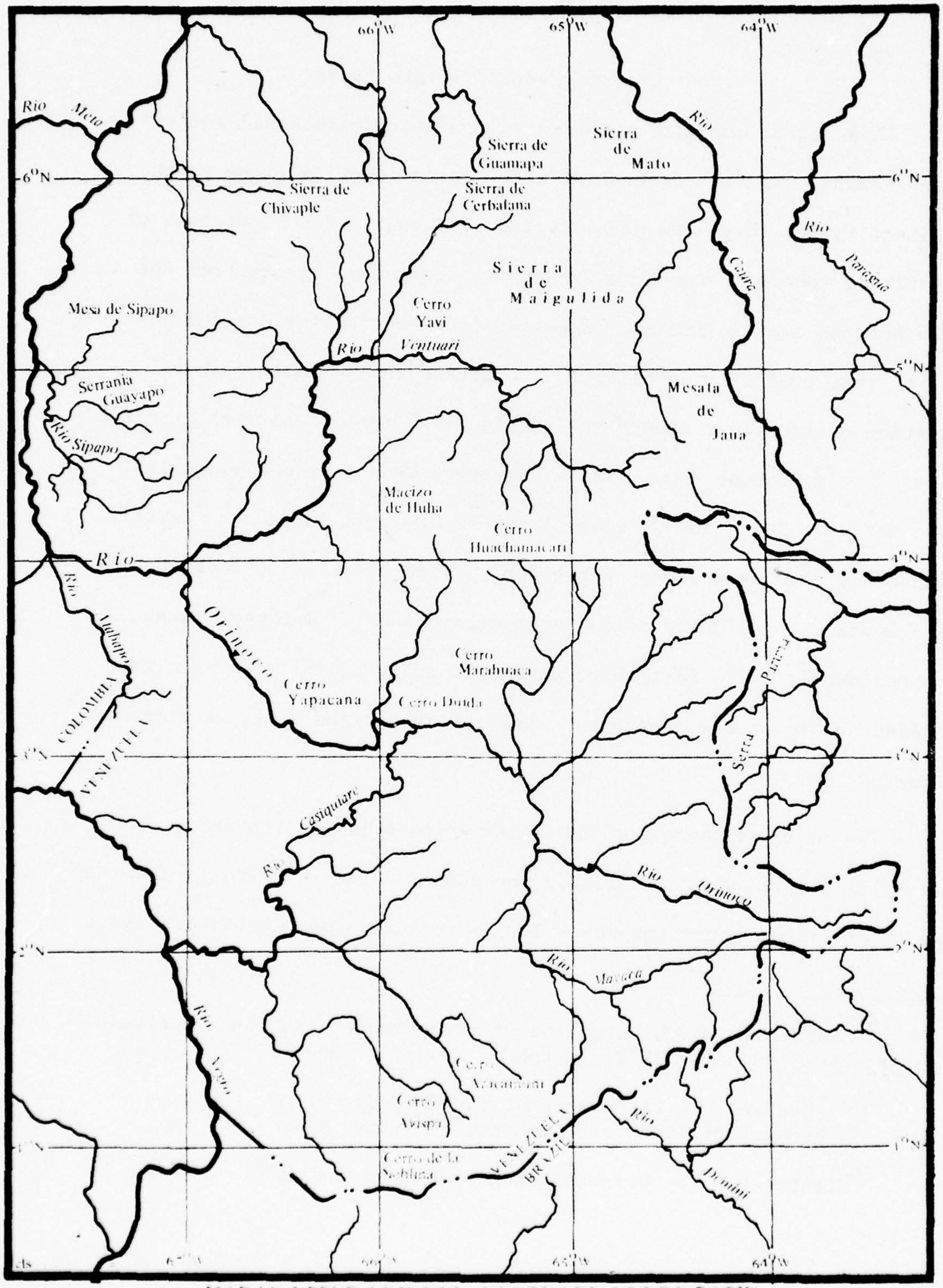
[17] Victor Lopez, "Venezuelan Guiana," in Handbook of South American Geology, ed. by William F. Jenks (New York: Geological Society of America, 1956), p. 334.




MAP 10 UPPER ORINOCO VENTUARI NEGRO BASIN

## Upper Orinoco-Ventuari-Negro Basin

This region contains a series of mountains with broad valleys intervening. Because several of these formations lie close to the Orinoco River, they have been studied in detail. The occurrence of granitic, rounded, sugarloaf mountains along the Orinoco from the Rio Meta to the Rio Atabapo suggested to Hitchcock the possibility of a giant granitic batholith.[18] Mountains to the east of this portion of the river appear as "castle-like" formations with granitic bases and sandstone caps. The sedimentary beds in these mountains are not flat lying and in several places are well folded.[19] Cerro Yapacana, along the banks of the Upper Orinoco, is 4,100 feet above sea level with slightly folded sedimentary rocks. The mesa rises approximately 3,700 feet above the surrounding plains and has been called an "immense sarcophagus" with a flat top and steep escarpments[20] (see Map 10).

The major tributary of the Upper Orinoco is the Ventuari, which rises in the Mesata de Jaua. To the north of the river there are many mesas and table mountains which lie in the Caura and Cuchivero Basins,

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[18] Charles B. Hitchcock, "The Orinoco-Ventuari Region, Venezuela," Geographical Review, XXXVII (October, 1947), p. 560.

[19] J. Grelier, To the Source of the Orinoco, trans. by H. A. G. Schmuckler (London: Jenkins, 1957), p. 46.

[20] Hitchcock, "The Orinoco-Ventuari Region," p. 528.

as well as many others which are in the Ventuari Basin. Several of these mesas, such as Mesa de Sipapo at 6,722 feet, can be readily observed from the Orinoco. To the south of the Mesa de Sipapo is the Serrania Guayapo with 7,500 foot high Cerro Guanay. One of the most intensely studied of the mountains of this region is Cerro Yavi, which lies in an area of dissected table mountains that appear as a "series of great jagged uplands."[21] Near the base of this mountain there is a series of 300 to 600 foot high ridges. A total thickness of 2,600 to 3,000 feet of the Roraima Series is exposed at Cerro Yavi. Here sedimentary rocks of the Roraima Formation are a gentle inclination towards the south.[22]

South of the Rio Ventuari lies another group of table mountains. This mass is divided into two separate groups, the Macizo de Huha and Cerro Duida. The Macizo de Huha covers approximately 8,263 square miles and contains several taller mesas. Cerro Huachamacari is a "layer cake-like mass" which reaches 6,400 feet.[23] Cerro Marahuaca, at 8,500 feet, is the tallest peak in this portion of the Guiana Highlands.

Directly south of Cerro Marahuaca lies Cerro Duida, which is beyond a doubt the most striking of the mountains of the Upper Orinoco Basin. Cerro Duida rises 7,000 feet above the Orinoco lowlands to a maximum elevation of 7,600 feet and is located within 10 miles

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[21] Ibid., p. 542.

[22] Ibid., p. 562.

[23] G. H. H. Tate and Charles B. Hitchcock, "Cerro Duida Region of Venezuela," Geographical Review, XX (1930), p. 49.

of the Rio Orinoco. The mesa covers 250 square miles and has escarpments up to 6,000 feet high. In this table mountain the sedimentary beds of the Roraima Series are strongly folded and steeply inclined. The top of the mountain is not a level plateau but rather an old erosional surface with a depression in the center.[24]

Farther up the Orinoco there are other table-like mountains which may be composed of the Roraima Series. The small Rio Mavaca is reported to rise in a series of sandstone mountains. Here the sedimentary beds are dipping rather than horizontal. The Sierra Guaharibo, which is also composed of sandstone, has sheer cliffs which rise 2,000 feet above the Orinoco.

The remaining mountains of the Orinoco-Ventuari-Negro Basin appear in an area bordered by the Rio Orinoco, Rio Negro, and Rio Casiquiare. The Rio Casiquiare connects the Rio Orinoco and Rio Negro with approximately 20 percent of the water of the Orinoco flowing via the Casiquiare into the Negro. Early European explorers such as Humboldt and Spruce reported the presence of flat-topped mountains within this area; however, little was known about the area until an expedition entered the area in the 1950s and located a group of mesas which rise to above 8,000 feet near the Venezuela-Brazil border. Within the area there are at least three large blocks of sedimentary rock forming mesas. The northern mesa, Cerro Aracamuni, reaches

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[24]H. A. Gleason, "Botanical Results of the Tyler-Duida Expedition," Bulletin of the Torrey Botanical Club, LVIII (May, 1939), p. 284.

5,200 feet and is located almost a hundred miles due south of Cerro Duida. Cerro Avispa in this same general area has a maximum elevation of almost 5,000 feet. The largest and farthest south of the mesas is Cerro de la Neblina. This mountain or high upland lies only a few miles from the Brazilian border. Here the Roraima Formation contains recent instrusions and, as at Cerro Duida, appears to have been strongly folded.[25] Cerro de la Neblina is from nineteen to twenty-five miles wide and about fifty miles long. The tallest peak in the Cerro, Pico Phelps, is reported to be 9,990 feet above sea level.[26] If this elevation is correct, it is the tallest peak in the Guiana Highlands.

Also included among the mountains of the Orinoco-Ventuari-Negro Basin are those of the Serra de Parima. This range is closely related to other parts of the Guiana Highlands; however, it has the overall appearance of being created by doming.[27] The central portion of this 1,000 by 60 mile range is composed of a coarse granite. There are several mesas, hogbacks, monoclinal ridges and flatirons of sandstones and conglomerates of the Roraima Series in the range.[28]

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[25] Charles D. Reynolds, "Notes on the Geology," Geographical Review, XLV (January, 1955), p. 49.

[26] Bassett Maguire and J. J. Wurdack, "The Position of Cerro de la Neblina, Venezuela," Geographical Review, XLIX (1959), p. 566.

[27] Hamilton A. Rice, "Air Photography in Geographical Exploration and in Topographical and Geological Surveying," American Journal of Science, CCXLIII-A (1945), p. 486.

[28] Hamilton A. Rice, "The Rio Branco, Uraricuera, and Parima," Geographical Journal, LXXI (February, 1928), p. 118.

## Sierra de Imataca

The Sierra de Imataca is the northernmost part of the Guiana Highlands. The 80 mile wide range begins southeast of Ciudad Bolivar and extends for approximately 100 miles to the delta of the Rio Orinoco.[29] To the southeast the range merges with the Mesata de Nuria, a tableland about 2,300 feet above sea level. From this mesata a low spur extends eastward into Guyana. The quartzites, which are the most resistent rocks of the Imataca Series, tend to form uplands and ridges. The entire range consists of a series of east to west oriented quartzite ridges which rise above the surroundings.[30] This part of the Sierra de Imataca resembles the inselberg and savanna areas of East Africa. Mountains or inselbergs of the range rise an average from 300 to 800 feet above the surrounding plains.

The most widely known mountain of the Sierra de Imataca is the "Iron Mountain," or Cerro Bolivar. This mountain is about two by six miles in size and contains isolated pockets of iron ore.[31] The mass, which rises 1,000 feet above its surroundings, was known to contain iron in the 1920s but was not exploited until the 1940s. Similar iron deposits occur in inselbergs to the south, east, and north of Cerro Bolivar.

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[29] Levi Marrero, Venezuela y Sus Recursos, (Madrid: Editorial Mediterraneo, 1964), p. 124.

[30] J. Kalliokski, "Geology of North Central Guyana Shield, Venezuela," Bulletin of the Geological Society of America, LXXVI (September, 1965), p. 1031.

[31] J. C. Ruckmick, "The Iron Ores of Cerro Bolivar, Venezuela," Economic Geology, LVIII (1963), p. 219.

Also in the Sierra de Imataca along the southern bank of the Rio Orinoco, a few miles downstream from the mouth of the Rio Caroni, are two black knobs of ferruginous quartzite. Here at Los Castillos Sir Walter Raleigh was defeated by the Spanish and his hopes for a British colony on the Orinoco were crushed.[32]

## PART VI

## SOILS OF THE GUIANA HIGHLANDS

Soil formation in tropical areas has been the subject of many studies. One problem with these studies is that they tend to be either extremely generalized or extremely detailed. In addition, only a few of the studies directly relate to the Guiana Highlands. As would be expected, the soils are closely related to the basic geology of the region. The basic intrusive rocks of the region generally weather into lateritic soils of varying fertility.[1] Many of the sedimentary rocks of the Roraima Series are composed of materials which have undergone weathering at an earlier period. Because of this, these materials are relatively resistant to additional erosion.

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[32] Liddle, Geology of Venezuela, p. 11.

[1] Dennys B. Fanshawe, The Vegetation of British Guiana: A Preliminary Review (Oxford: University Imperial Forestry Institute, 1952), p. 16.

This is especially true of the sandstones, which often are the source of infertile soils that consist almost entirely of quartz grains.[2] Most of the soils of the Guiana Highlands tend to be relatively infertile as a consequence of intense weathering.

### Soil Groups of the Guiana Highlands

Soils of the Guiana Highlands fall into four major categories or groups: Red-Yellow Podzols, Red Latosols, Reddish Laterite, and Lithosols. Red-Yellow Podzols are well-drained soils with a light textured upper horizon and heavy subsoils.[3] They are formed primarily from sandstones and quartzites. The parent materials lack significant concentrations of clay and the rapid percolation which occurs in some tropical areas creates acidic soils.[4] The soils of this category are generally shallow and sandy. The second category, Red Latosol soils, are formed by the process of laterization. Water percolating through the soils removes the silica from the soils. As the silica is removed, the concentration of iron and aluminum increases. These are contained in the soils as sesquioxides, concentrations of which give the soils

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[2] D. Bleakley and J. A. Khan, "A Note on the Soils of the White Sand Formation of British Guiana," in Proceedings of the 5th Inter-Guiana Geological Conference (Georgetown, British Guiana: Geological Survey of British Guiana, 1962), p. 169.

[3] W. G. Sombroeck, Amazon Soils (Wageningen, Netherlands: H. Veenman and Zn, 1966), p. 140.

[4] S. R. Eyre, Vegetation and Soils (Chicago: Aldine Publishing Co., 1968), p. 210.

their reddish color.[5] If the leaching process continues until most of the silica has been removed from the soils, the resulting materials are termed Reddish Laterite, another class of soils. Laterite, when exposed to the atmosphere, forms a very hard crust and in some areas is used as a building material. Lithosols are very shallow soils which occur on slopes with significant runoff. The rapid runoff limits leaching while removing the fine particles from the soils. These soils are most commonly composed of coarse sand and fine gravel.[6]

## Distribution of Soil Groups

The distribution of soils in the Guiana Highlands is difficult to discuss. One geography book regarding Venezuela contains a 14 page section on the soils of that nation. Treatment of this type all but ignores the area south of the Rio Orinoco. The four major soil types already described are reported to occur; however, their distribution is not indicated. The authors of the book point out the lack of research on this subject.[7] The distribution of soils indicated on Map 11 is very generalized; in many cases more than one of the four soil types occurs in an area indicated as having one soil type. The

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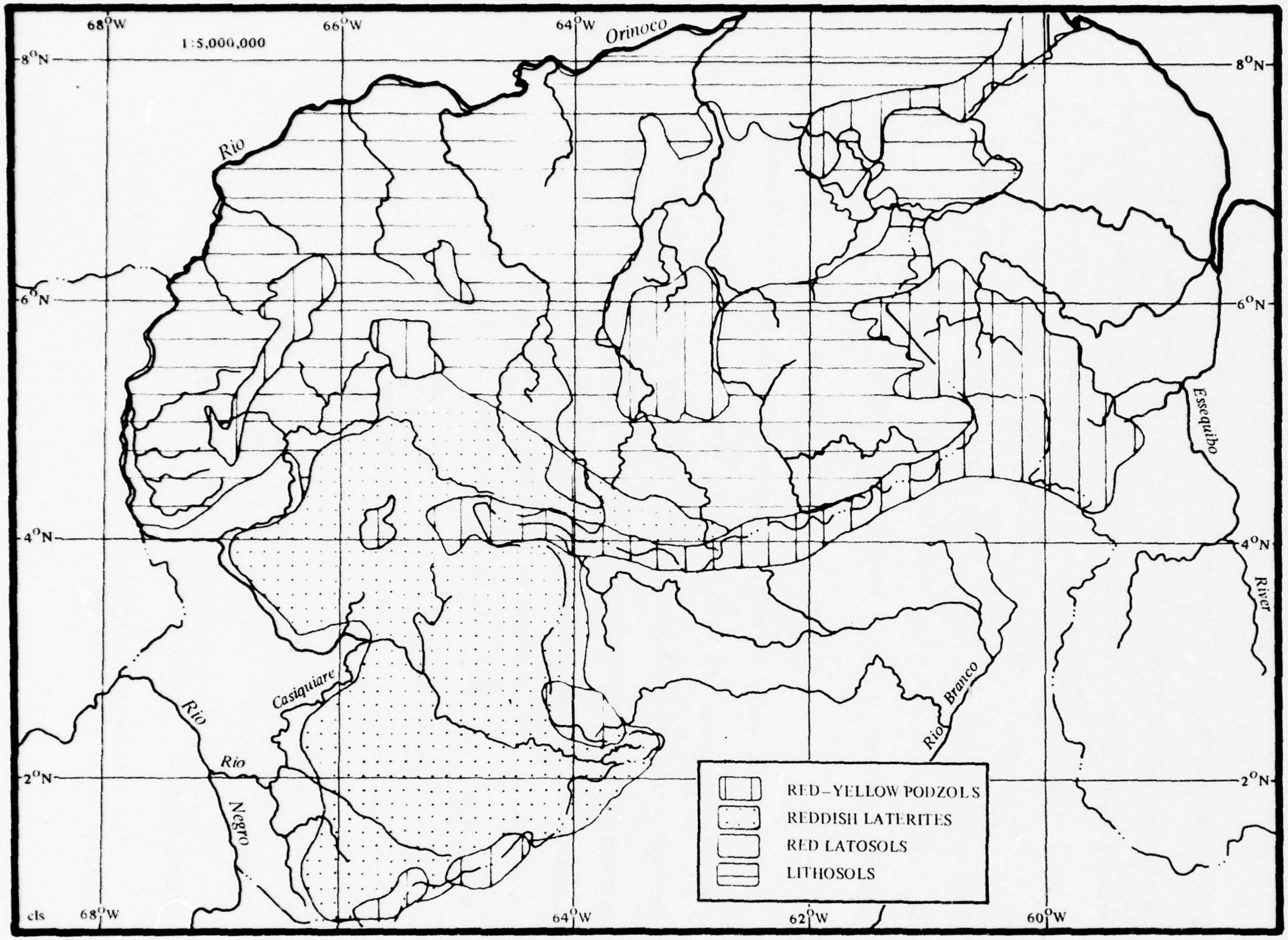
[5] Arthur N. Strahler and Alan H. Strahler, Elements of Physical Geography (New York: John Wiley and Sons, Inc., 1976), p. 167.

[6] Brian T. Bunting, The Geography of Soils (Chicago: Aldine Publishing Co., 1967), p. 116.

[7] Levi Marrero, Venezuela y Sus Recursos (Madrid: Editorial Mediterraneo, 1964), p. 307.




MAP 11 SOILS OF THE GUIANA HIGHLANDS

soil type indicated covers a majority of the area but not all of the area; for example, in an area where Red Latosols occur on ridges, hills, and mountain tops, they are often replaced by Lithosols on the steeper slopes.[8]

# PART VII

# VEGETATION OF THE GUIANA HIGHLANDS

## Vegetation Formations

The Guiana Highlands has many patterns of natural vegetation, which are separated into several biomes such as forests and savannas. Biomes are divided into formation classes such as rain forests. These formations are primarily the consequence of the combined interaction of elevation, climate, soils, drainage, geology, topography, and other factors. Vegetation formations present in the study region include rain forests, deciduous forests, cloud forests, savannas, and chaparral.

### Rain Forests

Rain forests are dense stands of trees and other vegetation which reach heights of 90 to over 100 feet above the ground. There are four layers, or strata, of tree canopies; these canopies are extremely difficult to observe from the floor of the forest. The top canopy, which is not continuous, consists of trees with large umbrella-shaped crowns. Crowns of the lower trees tend to be more crowded and compressed.

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[8] U.S. Army, Engineer Agency for Resources Inventory, Venezuela: National Inventory of Resources (Washington, D.C.: U.S. Army, 1968), p. T-5.

The trees of each strata may differ taxonomically; yet, structures such as leaves are often very similar in form. The tree trunks are often buttressed; however, the reasons for this have not been determined. The factor which unites the many thousands of species of trees in the rain forest is that they are all broad-leafed, evergreen species. Palms are relatively rare in the rain forests of the Guiana Highlands. There are also numerous lianas, or vines, in the rain forest which may twist and climb as much as 200 feet before reaching the upper canopy. The rain forest formation has been divided into numerous subformations: one study in Guiana reported the occurrence of seven distinct subformations of rain forest.[1]

### Deciduous Forests

Often called semi-evergreen forests, this formation differs from rain forests because of overall height and because not all trees are evergreens. Here the upper story reaches 60 to 70 feet and is dense rather than discontinuous; the 30 foot tall understory is also dense. Vines are much more common in the deciduous forests, while trunk buttresses are rare. There are numerous evergreen species of trees in this formation, but at least 20 to 30 percent of the trees are deciduous.

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[1] Miles Haman and B. R. Wood, "The Forests of British Guiana," Tropical Woods, XV (September, 1928), p. 5.

## Cloud Forests

Cloud forests generally have two stories, with the tallest trees characterized by gnarled trunks and the lower ones forming a dense shrub layer. Cloud forests have a larger number of tree species than do the rain forests and may include large stands of bamboo. As elevation increases, the canopy of the cloud forest gradually lowers until eventually only a very dense mass of vegetation occurs near the ground. This form of cloud forest has been called an elfin woodland.

## Savanna

One of the major biomes of the world is the savanna. Savannas vary from savanna woodlands, which contain significant tree growth, to savanna grasslands, which have few trees. The savannas of the Guiana Highlands are primarily of the savanna grassland type. In these savannas the grasses may completely cover the ground or may occur in scattered bunches. The individual plants range from only a few inches tall to 12 feet. Located along the major streams and rivers of the savannas are gallery forests, which are dense tree formations with one or more stories and numerous palms.[2] Savanna grasslands also occur at higher elevations in the Guiana Highlands such as on the tops of the mesas. There is little information available concerning the composition of these savannas other than detailed analysis of very small areas.

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[2] Llewelyn Williams, "Forests of the Venezuelan Guiana," Tropical Woods, LXVIII (1941), p. 18.

Chaparral

This formation is a dry transition between the savanna and forest biomes. Some studies consider it to be part of the savannas; others present it as part of the forest biome. The formation consists of grasses mixed with bushes, shrubs, and trees. Trees in the formation are commonly gnarled, low branched with leathery leaves. Throughout chaparral, grasses are the dominant form of vegetation.

## Distribution of Vegetation Formations

The relationship of vegetation to geology, geomorphology, and soils is clear if several correlations are kept in mind. Where the sedimentary rocks of the Roraima Formation have formed infertile sand and loams, the vegetation tends to be sparse and more often of the grassy savanna and chaparral type. Where intrusive igneous or metamorphic rocks have evolved into richer soils, the vegetation is generally forest. In locations where the soils have been derived from a combination of these two classes of rocks, forests are often the dominant formation. However, due to localized burning of the vegetation by the inhabitants, savannas may occur in areas which could produce forests (see Map 12).

Elevation also has an important effect upon the vegetation of the Guiana Highlands. As a general rule, at the lower elevations and under ideal conditions, rain forests will be the dominant vegetation formation. At higher elevations, the deciduous forests may be dominant,

and if the elevation is increased, these may be replaced by cloud forests. The rain forests of the Amazon Basin are replaced by other formations at about 2,500 feet.[3]

Climate also plays a role in the distribution of vegetation in the region. This role may also be the result of elevation and topography. Where there is a dry season in part of the year, the rain forests are replaced by deciduous forests or savanna.

There is a certain amount of overlap of categories, and areas of differing vegetation occur within an area shown as having only one formation. At lower elevations in the northern portion of the Guiana Highlands, savanna and chapparal formations are dominant. In the Sierra de Imataca these are the main vegetation formations, with the hills and ridges of the region appearing as forested islands rising above the savanna. South of the savanna and chaparral, and at slightly higher elevations, particularly in the extreme east and southwest, rain forests are the dominant vegetation formation. At still higher elevations deciduous forests and mixed deciduous-rain forests occur. Scattered throughout the Guiana Highlands are large patches of savanna vegetation. Much of the Gran Sabana is covered by this form of vegetation, as are large areas of the Pakaraima Mountains. Isolated patches of savannas occur to the west of the Gran Sabana. The occurrence of these patches of grasslands closely correlates with the occurrence

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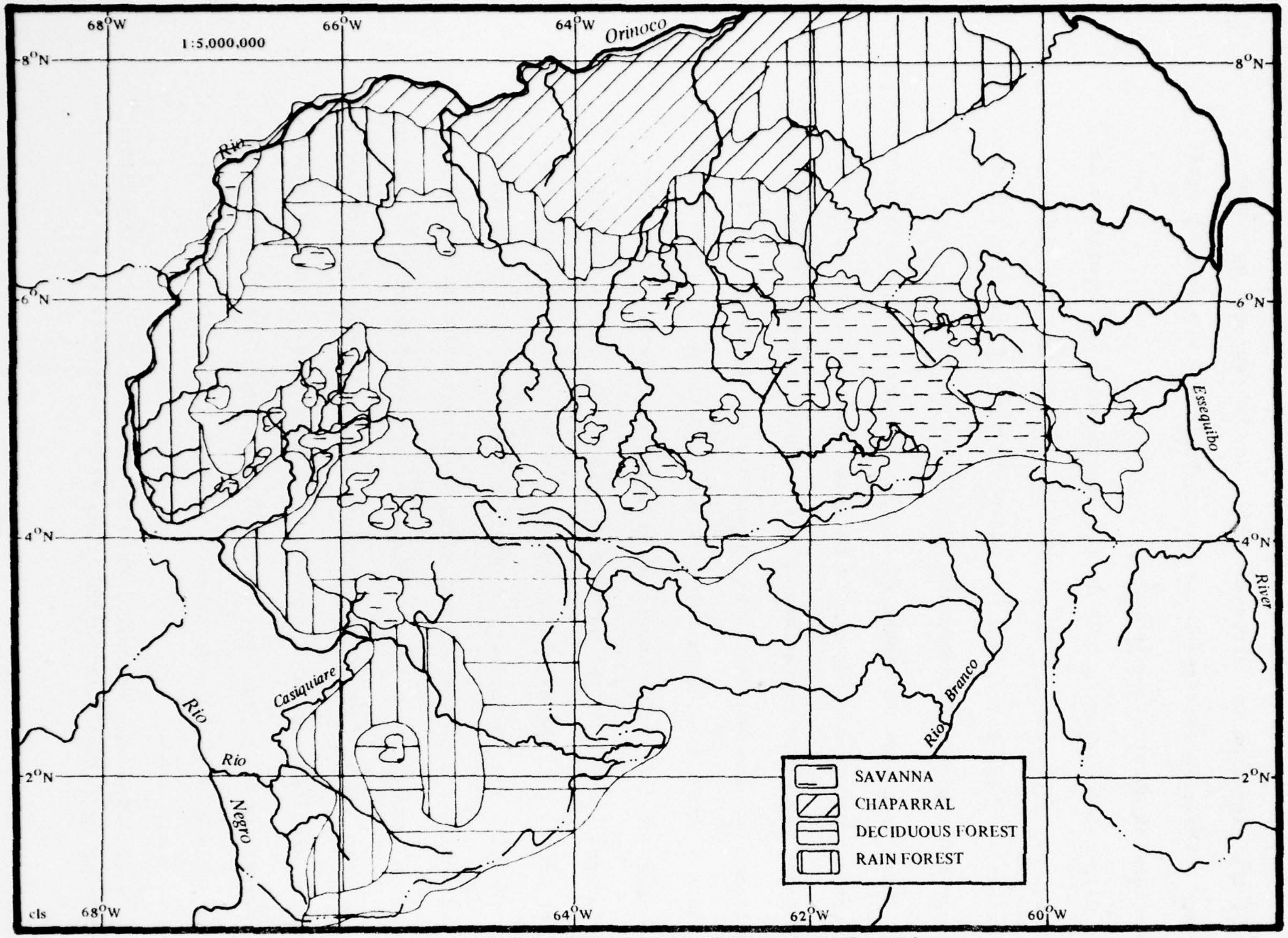
[3]H. A. Gleason, "Botanical Results of the Tyler-Duida Expedition," Bulletin of the Torrey Botanical Club, LVIII (May, 1931), p. 278.



MAP 12 VEGETATION OF THE GUIANA HIGHLANDS

of sedimentary rocks of the Roraima Series or with soils derived from these rocks. At the highest elevations of the Guiana Highlands, the savanna and deciduous forests are replaced by cloud forests. With increased elevation, the cloud forest itself is replaced by a moist formation of low grasses, mosses, lichens, and bare rock. This latter is common in portions of Mount Roraima, Cerro Duida, Cerro de la Neblina, and Auyan-Tepui, but covers too small an area to be indicated on Map 12.

## PART VIII

## CONCLUSIONS

Descriptions of the geology, geomorphology, terrain, soils, and vegetation of the Guiana Highlands make possible formulation of a system of physiographic sections for the province. The units used to present data in parts of this report were based upon the physiographic sections devised by Victor Lopez.[1] However, his use of river basins as subdivisions creates the strong potential for overlap of information concerning a feature which is located on the water divide of two basins.

To avoid the use of such sections, the analysis of the relation of soils, vegetation, landforms, and geology was necessary to facilitate development of more meaningful physiographic sections. This analysis

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[1]Victor Lopez, "Venezuelan Guiana," in Handbook of South American Geology, ed. by William F. Jenks (New York: Geological Society of America, 1956), p. 333.

was conducted at small scale due to the lack of specific data. Overlays were prepared for each type of data and were superimposed; then in many cases the relationship between the various data types was readily apparent.

At the generalized scale of the maps, comparison of soils with surface configuration showed that distribution of soil types was not strongly related to landforms. In spite of this, some generalizations are possible. The Red-Yellow Podzols occur in areas of hills and mountains, but not in areas of plains. Reddish Laterites occur primarily in areas of plains.

Thus, there is a distinct relation of laterites with plains, and another relation between podzols and hills or mountains. At more localized scales, the Lithosols are obviously associated with areas with steep slopes and exposed rock. As mentioned earlier, Red Latosols are common on ridges, hills, and mountain slopes, but are replaced by Lithosols on steeper slopes.

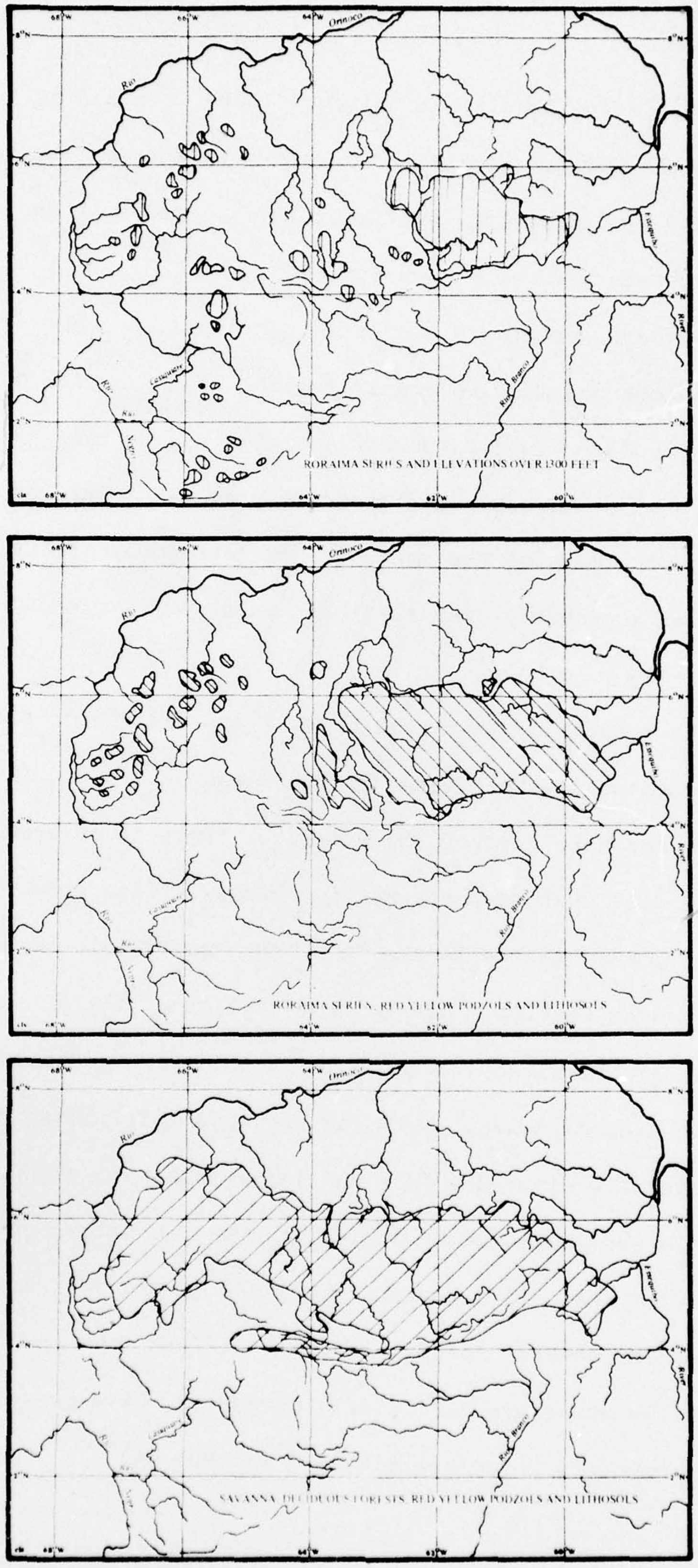
Relating geology to the soil types shows that the Red-Yellow Podzols and Red Latosols are predominant in areas where the sedimentary rocks of the Roraima Series occur. The intrusive rocks of the Imataca Series and intrusive rocks within localized areas of the Roraima Series are often the source of lateritic soils.

Comparison of vegetation formations and soil type indicates that rain forests, deciduous forests, and savannas occur in the areas of Red-Yellow Podzols and Red Latosols. Chaparral is generally restricted

to areas of Lithosols and Reddish Laterites. There is a distinct relation between the Roraima Series and savannas in the eastern portion of the region, and a similar but lower correlation between these two factors in the western portion of the region.

In general, there appears to be little correspondence between vegetation formations and surface configuration. This conclusion goes against several studies of a limited area which indicate that several strong correlations occur. This difference may be the result of generalization in the maps of the region. The correlation between vegetation and soils probably is reflected in a vegetation/landform relation.

Based on the results of this analysis, it appears that three physiographic sections in the Guiana Highlands can be defined (see Map 13). In the northern part of the province, there is an area of rolling lowlands with east-to-west trending ridges. This area correlates very closely to the Sierra de Imataca and should be named the Sierra de Imataca Section. The eastern portion of the Guiana Highlands, south of the first section but east of the Rio Paragua, is a distinctive area of mesas. Here the numerous large mesas have steep escarpments of sedimentary rock and large areas of savanna vegetation. This section could be called the Tepui Section, after the Indian term for mesa. The Western Highlands to the west of the Rio Paragua contains several large mesas. It differs from the Tepui Section in that the mesas are more widely dispersed, have denser vegetation, and more rounded slopes (see Figure 1 and Map 14).

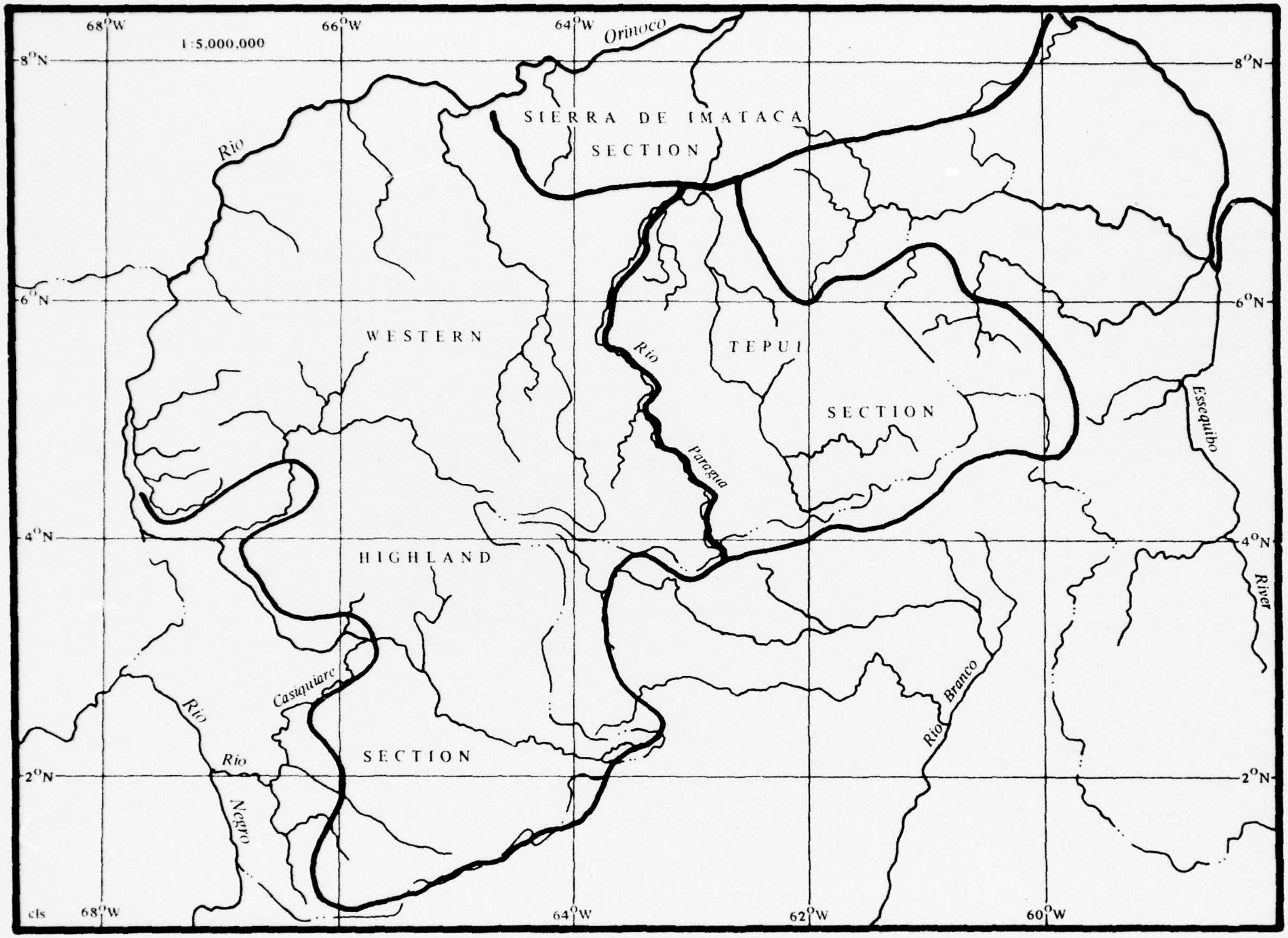



MAP 13 CORRELATION OF FACTORS

FIGURE 1

PHYSIOGRAPHIC SECTIONS OF THE GUIANA HIGHLANDS

| Section | Sierra de Imataca | Tepui Section | Western Highlands |
|---|---|---|---|
| Topography | Rolling plains with ridges 100 to 200 feet local relief. | Numerous large mesas and table mountains. | Hills and mountains with some mesas. Mesas generally lower and smaller. |
| Geology | Intrusive materials of the Imataca Series with concentrations of iron. | Numerous outcrops of Roraima Series 7,600 feet thick. | Igneous material in places capped with Roraima Series. Roraima 2,500 feet thick. |
| Soils | Red-Yellow Podzols in east; Red Latosols in west. | Lithosols and Red-Yellow Podzols. | Lithosols with Red-Yellow Podzols, and Lithosols replacing latosols on steep slopes. |
| Vegetation | Savannas with forests on the ridges. | Mixture of savannas and deciduous forests. Rain forests and cloud forests. | Deciduous forests with scattered savannas. Rain forests and cloud forests in small areas. |




MAP 14 PHYSIOGRAPHIC SECTIONS OF THE GUIANA HIGHLANDS

As this scheme of physiographic sections shows, the Sierra de Imataca appears to be distinct from the remainder of the Guiana Highlands. This difference is the result of overall appearance, geology, and landforms. Additional study may demonstrate that it should not be considered a part of this region, but should instead be considered a portion of the Guiana Hills physiographical province of the Guiana Shield.

Available data suggests that additional research may provide sufficient information to subdivide the Western Highlands Section into two physiographic districts. Formation of such units would be based upon the occurrence of a greater amount of upland in the Upper Cuchivero area than in the region between the Rio Ventuari and Rio Negro.

The arrangement of physiographic sections in the Guiana Highlands, as presented in this report, should allow further study of the region to be organized without separating the area into unrealistic and often unworkable units such as those based on drainage basins.

## LIST OF REFERENCES


Andre, Eugene. A Naturalist in the Guianas. London: Smith, Elder and Co., 1904.

Barbosa, O., and de Romos, A. "Principle Aspects of the Geomorphology and Geology in the Territory of Rio Branco, Brazil." Proceedings of the 5th Inter-Guiana Geological Conference. Georgetown: Geological Survey of British Guiana, 1962.

Bateson, J. H., and Allderidge, M. G. "Geology of the Potaro Square." Proceedings of the 5th Inter-Guiana Geological Conference. Georgetown: Geological Survey of British Guiana, 1962.

Bleakley, D., and Khan, J. A. "A Note on the Soils of the White Sand Formation of British Guiana." Proceedings of the 5th Inter-Guiana Geological Conference. Georgetown: Geological Survey of British Guiana, 1962.

Bracewell, Smith. "British Guiana." Handbook of South American Geology. Edited by William F. Jenks. New York: Geological Society of America, 1956.

Bunting, Brian T. The Geography of Soils. Chicago: Aldine Publishing Co., 1967.

Cordani, U. S.; Melchel, G. C.; and de Almeida, F. F. M. "Outline of the Precambrian Geochronology of South America." Canadian Journal of Earth Sciences, V (1968), 628-632.

Crampton, Henry E. "Kaieteur and Roraima: The Great Falls and Great Mountain of the Guianas." National Geographic, XXXVIII (September, 1920), 227-284.

Dixon, C. G. "Notes on Basic Igneous Rock in British Guiana." Proceedings of the 5th Inter-Guiana Geological Conference. Georgetown: Geological Survey of British Guiana, 1962.

Eyre, S. R. Vegetation and Soils. Chicago: Aldine Publishing Co., 1968.

Fanshawe, Dennys B. The Vegetation of British Guiana: A Preliminary Review. Oxford: University Imperial Forestry Institute, 1952.

Fenneman, N. M. "Physiographic Boundaries Within the United States." Annals of the Association of American Geographers, IV (1914), 84-134.

Gansser, A. "Observations on the Guiana Shield (South America)." Ecolog. Geol. Helv., XLVII (1954), 77-112.

Garner, H. R. "Derangement of the Rio Caroni, Venezuela." Revue de Geomorphologie Dynamique, XVI (1966), 54-83.

Gleason, H. A. "Botanical Results of the Tyler-Duida Expedition." Bulletin of the Torrey Botanical Club, LVIII (May, 1931), 277-404.

Grelier, J. To the Source of the Orinoco. Translated by H. A. G. Schmuckler. London: Jenkins, 1957.

Haman, Miles, and Wood, B. R. "The Forests of British Guiana." Tropical Woods, No. 15 (1 September 1928), 1-13.

Hartshorne, Richard. Perspective on the Nature of Geography. Chicago: Rand McNally and Co., 1959.

Hawkes, D. D. "Petrology of Guiana Dolerites." Geology Magazine, CIII (1966), 330-335.

Hitchcock, Charles B. "The Orinoco-Ventuari Region, Venezuela." Geographical Review, XXXVII (October, 1947), 525-566.

Kalliokoski, J. "Geology of North Central Guayana Shield Venezuela." Bulletin of the Geological Society of America, LXXVI (September, 1965), 1027-1049.

Lake, M. C. "Cerro Bolivar: U.S. Steel's New Iron Ore Bonanza." Engineering and Mining Journal, CLI (August, 1950), 74-83.

Liddle, Ralph A. Geology of Venezuela and Trinidad. Ithaca, New York: Paleontological Research Institute, 1946.

Lopez, Victor. "Venezuelan Guiana." Handbook of South American Geology. Edited by William F. Jenks. New York: Geological Society of America, 1956.

Lopez, Victor; Mencher, E.; and Brineman, J. H. "Geology of Southeast Venezuela." Bulletin of the Geological Society of America, LIII (1942), 849-872.

McConnell, R. B. "Planation Surfaces in British Guiana." Geographical Journal, CXXXIV (December, 1968), 506-520.

Maguire, Bassett. "Cerro de la Neblina, Amazonas Venezuela." Geographical Review, XLV (January, 1955), 27-51.

Maguire, B., and Wurdack, J. J. "The Position of Cerro de la Neblina, Venezuela." Geographical Review, XLIX (1959), 566-569.

Marrero y Articles, Levi. Venezuela y Sus Recursos. Madrid: Editorial Mediterraneo, 1964.

Philipson, W. R.; Doncaster, D. C.; and Idrobo, J. M. "An Expedition to the Sierra de la Macarana, Colombia." Geographical Journal, CXVII (1951), 188-199.

Reynolds, Charles D. "Notes on the Geology." Geographical Review, XLV (January, 1955), 49-50.

Rice, Hamilton A. "The Rio Branco, Uraricuera and Parima." Geographical Journal, LXXI (February, 1928), 115-145.

Rice, Hamilton A. "Air Photography in Geographical Exploration and in Topographical and Geological Surveying." American Journal of Science, CCXLIII-A (1945), 496-494.

Ruckmick, J. C. "The Iron Ores of Cerro Bolivar, Venezuela." Economic Geology, LVIII (1963), 218-236.

Schols, H. "Surinam." Handbook of South American Geology. Edited by William F. Jenks. New York: Geological Society of America, 1956.

Singh, W. "Cordierite in the Pre-Cambrian Rocks of the South Savannas, British Guiana." Geological Magazine, LIII (1966), 36-43.

Smith, Guy-Harold. Physiographic Diagram of South America. Maplewood, New Jersey: Hammond, Inc., undated.

Snelling, N. J. "Age of the Roraima Formation, British Guiana." Nature, LXLVIII (15 January 1960), 1079-1080.

Sombroek, W. G. Amazon Soils: A Reconnaissance of the Soils of the Brazilian Amazon Region. Wageningen Netherlands: Centre for Agricultural Publications and Documents, 1966.

Stan, J. C. "Geology, Petrology and Iron Deposits of the Guiana Shield, Venezuela." Economic Geology, LVIII (1963), 70-83.

Stockley, G. M. Geology of British Guiana and the Development of Its Mineral Resources. Georgetown: British Guiana Geological Society, 1955.

Strahler, Arthur N. Introduction to Physical Geography. New York: Wiley and Sons, 1945.

Strahler, Arthur N., and Strahler, Alan H. Elements of Physical Geography. New York: John Wiley and Sons, Inc., 1976.

Tate, G. H. H. "Auyantepui: Notes on the Phelps Venezuelan Expedition." Geographical Review, XXVIII (1938), 452-474.

Tate, G. H. H., and Hitchcock, Charles B. "Cerro Duida Region of Venezuela." Geographical Review, XX (1930), 31-52.

U.S. Department of the Air Force, Arctic, Desert, Tropic Information Center. Survival Geography of South America: A Survey of the Jungles and Deserts of South America. Montgomery, Alabama: Air University, undated.

U.S. Department of the Army, Engineer Agency for Resources Inventory. Venezuela: National Inventory of Resources. Washington, D.C.: U.S. Army, 1968.

Van Riper, Joseph. Man's Physical World. New York: McGraw Hill, Inc., 1971.

Villa, Marco-Auralio. Geografia de Venezuela. Buenos Aires: Fundacion Eugenio Mendoza, 1961.

Vinckers, H. Beckering. "New Data on the Table Mountain Area." Proceedings of the 5th Inter-Guiana Geological Conference. Georgetown: Geological Survey of British Guiana, 1962.

Williams, Llewelyn. "The Caura Valley and Its Forests." Geographical Review, XXXI (1941a), 414-429.

Williams, Llewelyn. "Forests of the Venezuelan Guiana." Tropical Woods, No. 68 (1941b), 13-40.

Williams, Llewelyn. "Natural Resources of Venezuela." Cronica Botanica, VII (March, 1942), 75-77.

Wilson, Eugene. "Eastern Llanos and Guiana Highlands Savannas." Paper presented at the Southeast Regional Meeting of the Association of American Geographers, Boone, North Carolina, 1972.

Zahl, Paul. "Two Waterfalls in British Guiana." Geographical Journal, XLIII (1930), 521-522.